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Science Policy Study—Hearings Volume 9
SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

ORIGINAL

HEARINGS

BEFORE THE

TASK FORCE ON SCIENCE POLICY

OF THE

COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

JULY 9, 10, 11, 23, 24, 25, 1985

[No. 102]

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Committee on Science and Technology

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I

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SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

TUESDAY, JULY 9, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to notice, at 9:33 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (acting chairman of the task force) presiding.

Mr. Walgren. Let me call us to order and start.

Today the task force opens 6 days of hearings on the topic of scientists and engineers and their supply and demand.

These hearings are part of our larger study of the U.S. science policy that is being undertaken by this task force of the Committee on Science and Technology, especially under the impetus of the chairman of the full committee, Congressman Fuqua. He is unable to be here this morning and expresses his regrets, particularly to the witnesses that will be here today, but he has an unavoidable conflict, and I want to assure you that he will be most interested in the dialog that we have today, and it will not be lost for his absence.

Of course, we could not have science and engineering without scientists and engineers. So the subject today is central to the study that the task force has undertaken. Because our work force is produced largely by our education system, we need to look closely at that part of our society.

We should emphasize that the task force is focusing on science and engineering education in relationship to research as opposed to the general level of scientific literacy in the population as a whole. Because of that focus on what we will refer to as the professional level, we are concentrating primarily on advanced education, and we recognize that there is a student pipeline effect in this area, and that we certainly have to consider the pipeline that feeds advanced education programs. But for the purposes of our focus, we want to center in on the advanced educational level in this process.

Let me also note that we have asked the Office of Technology Assessment to report on how demographic trends affect the numbers in the science and engineering work force, and we will have a followup hearing on their report next spring.

This is a 2-year effort by the task force. It will not spring from the ground tomorrow but will be developed over the next year. So we are going to be looking at that factor in hearings that are scheduled next year.

Today's hearings will focus on other issues concerning the effectiveness of Federal programs in education. Whenever possible, we are trying in this exploration to develop some quantitative basis for looking at the questions that arise.

It is pretty clear that many decisions are taken by the Congress without being fully grounded in existing data and factual base, and we hope that in this process we can develop this dimension of the science policy questions so that the actions that follow on will be more closely tied to the facts as we actually experience them.

One of the panels during these 6 days of hearings will look at the data itself, including its completeness, its accuracy, and its usefulness for policy decisions in hopes of giving us some guides in that area.

Today's hearing is divided into two sections. The first will present us with an overview of science and engineering education and a brief review of past Federal support programs, and the second panel will address the work force supply and demand situation from their perspective in several different areas.

So let me welcome our first panel to the hearing. We have several groups that have submitted written testimony to us, and I know that without objection from the other members of the task force, those written submissions will be made part of this hearing record.

I also would invite the witnesses themselves to feel free to expand on their testimony in writing if there are points that they feel, in afterthought, would be good to develop for the record, and we will be most happy to have those submissions.

PANEL I

So now let me introduce our first panel. Dr. David Hamburg is president of the American Association for the Advancement of Science, and Dr. Alan Fechter is the executive director of the Office of Scientific and Engineering Personnel of the National Research Council.

We are glad to have you come and join in this hearing process, and we look forward to your testimony. Written testimony will be made part of the record, certainly, absolutely, and you can feel free to summarize or outline or develop in full the views that you have brought to us.

So, with that for introduction, let me turn to Dr. Hamburg and welcome him to the committee.

STATEMENT OF DR. DAVID A. HAMBURG, PRESIDENT, THE CARNEGIE CORP., NEW YORK, NY, AND CHAIRMAN, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC, ACCOMPANIED BY DR. WILLIAM G. WELLS, JR., AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Dr. **Hamburg**. Thank you very much, Mr. Walgren.

It is a privilege to be here. I am very glad to have Dr. William Wells on my right, from the AAAS staff and formerly a member of the staff of this committee. We worked together in preparing the written statement, which is rather extensive, and I will not read it.

I am awfully glad to be here. This morning, coming down on the plane, I cast my mind back on how this would have looked to me as a boy growing up in a small town in southern Indiana, very far in every way from the national decisionmaking process, and if anybody had told me I would have this kind of opportunity to sound off in this kind of setting, I would have thought him slightly mad. But here I am, and I am happy to sound off, especially on behalf of the AAAS, because it seems to me this whole enterprise of the committee is a very thoughtful, carefully prepared, systematic, long-term way in which you are addressing the great questions of national science policy. It is a good time for it and a good place for it.

There are probably no issues of greater importance in today's rapidly—and I do mean rapidly—transforming world than how we can keep science and technology strong, vital, dynamic, creative, innovative; how science and technology can serve society rather than dominate it; how we can learn, in the new world we have so recently made in the past few decades, and how to use science and technology more wisely for humane and decent purposes.

Now, the AAAS is so large, covering as it does all of science and the applications of science and its uses in everyday life, that we tend to get, or try to get, an overview of the entire field from our members, our board and council, our study groups, and our publications, especially the flagship publication, *Science*.

Now, let's start by trying to put first things first. What are we trying to do? Indeed, the bulk of my statement is an attempt to say what are we trying to do in an inquiry of this sort: what are some vaguely approximating principles that are worth keeping in mind from our national experience and the experience of other countries in this kind of enterprise?

Maybe the key points I want to make about values and processes worth preserving in our science system were best stated for me, at least, in an experience that I happened to have in 1976 when I was attending the Nobel ceremonies in Stockholm in December. The Chairman of the Nobel Foundation, Prof. Sune Bergstrom, a great biochemist himself, gave a statement about what was happening that year.

What happened that year was that the Americans won all the Nobel Prizes, every single one, and he started by asking, was this a gift of the various Nobel committees to the Americans in their bicentennial year? Then he went on to explain how that really could not happen, fond as they might be of the Americans.

He pointed out that in fact the Americans had been winning a large proportion of the Nobel Prizes for the preceding quarter century, and the really interesting question was not why the Americans won them all that year but why Americans had been winning so many Nobel Prizes and in other ways, clearly, manifestly demonstrating the strength of American science.

He gave it very concisely, and let me read it to you quickly:

> First, the recognition that basic science can have powerful practical consequences. Second, generous immigration policies which permitted many outstanding scientists from Europe and Asia and elsewhere to come to the United States.
>
> Third, the recognition of the importance of science and technology for economic progress. Fourth, the intellectual stimulation and fostering of innovation made possible by political freedom and open communication. Fifth, the strong national com-

mitment to support of basic science through institutions such as the NSF and the NIH.

Sixth, the democratic atmosphere of American universities and their laboratories, in contrast with the hierarchical, authoritarian structures prevailing in many other countries,

including many of the democracies of Western Europe at that time.

And, seventh, special attention to the fostering of research and providing opportunities for talented and dedicated young people.

He then pointed out that other democratic societies were moving rapidly to emulate these American conditions, and they were making tangible, rapid progress, and indeed they have. In the not quite decade since that speech of Bergstrom's, I would say that the Western European countries and Japan have made great progress in providing conditions much more like those which were so successful in our science in the preceding period.

But I do think, as a matter of fact, in the period 1975 to 1980, when I was president of the Institute of Medicine for the National Academy of Sciences, I had a number of international science policy seminars, chiefly in the life sciences but extending somewhat beyond that, and I would say that, over and over again, the factors that Bergstrom laid out came through loud and clear as factors contributing greatly to the excellence of American science.

I think that does put in a capsule some things we are trying to do in this country, and they are worth keeping in mind, still very valid criteria, opportunities for progress in the field.

Now, Bergstrom put a lot of emphasis on basic science because it is so much easier to see the attractiveness of the applications of science, the uses of science and technology; harder to see that support of science for its own sake may have a variety of applications in the future in ways that cannot even be anticipated.

That recognition for us in this country was chiefly a World War II phenomenon. I think that the very image of a sort of wild longhair like Albert Einstein, a manifestly impractical man, contributing ideas that could come down to something so practical as atomic weapons, made a very deep impression on the public at large, and other things of that sort. The intensely practical role for the universities in World War II was another factor there.

So I think we came to shift somewhat from craftsmanship per se to an understanding that a very strong science base, a very broad science base, could contribute to practical applications in many ways in the future. Part of that has evolved in this country, part of the strength has been an intimate interplay between basic and applied science.

To give you one example of great importance for the modern life sciences, the discovery that DNA is a genetic material. There is hardly any more basic discovery than that. It was made in the early forties at the Rockefeller University in New York by Avery, McCloud, and McCordy, who were in fact trying to understand pneumonia. They really wanted a vaccine for pneumococcal pneumonia, which was a tremendous killer in that preantibiotic era. In doing so, they wanted to understand the nature of the pneumococcus, the bacterium that caused the infection, and in doing that, they transformed one kind of pneumococcus to another and found that by shifting DNA from one kind to another, it would breed true and that, therefore, DNA was a genetic material. So a fundamental discovery in basic science with wide-ranging implications, for example, for the creation and emergence of new technology was growing out of an applied interest. So that kind of fostering of interplay between basic and applied research has been another of the great strengths in this country.

Now, we have had some premonition over a century or so that we were going to have to look more and more to basic science to generate technological advances, even though we were remarkably successful, for example, through our great inventors in getting technological advances through a kind of commonsense craftsmanship and an effort to apply existing technology to the great natural resources of the country. But even so, when President Lincoln established the National Academy of Sciences in the Civil War period, and again when President Wilson established the National Research Council in the World War I period, there was this perception that you would need the whole broad, multifaceted scientific community, basic as well as applied sciences, in order to cope with the wartime problems, yes; but increasingly in order to contribute to peacetime advance.

Since World War II, we have seen a vast institutionalization of science, almost unprecedented, heavily based in our universities, more so in this country than elsewhere. That institutionalization of science has generated basic advances beyond our wildest dreams, and you put that in the context of economic freedom and political freedom, and you get a tremendous ferment in technological innovation which affects the economy profoundly, and that in turn affects the whole society.

Now, the rate of change generated by that set of interrelated factors I have just mentioned really pushes us toward adaptability, perhaps beyond anything that has gone before in human experience. Rate of change means that you have to have adaptable individuals, organizations, and institutions not only to generate advances that can have economic and social benefit but to sort out the beneficial from the adverse effects of these very rapid changes and accommodate to the social dislocations.

In the case of the individual career span, that means lifelong learning. It means being prepared to shift to take advantage of new scientific opportunities as they arise. And it means probably that we have to put more emphasis than we have in the past on a broad basis of education in the sciences so that individuals are in a position to make shifts as they go down the line; that is to say, they are not too locked into a kind of narrow hyperspecialization which puts them in a position to do one thing and one thing only.

I also want to call your attention to a body of research identified chiefly with the great economist, Theodore Schultz of the University of Chicago, but contributed by many other people, which shows in a variety of cultures, both developing countries and technically advanced countries, the immense rewards of investment in human capital. We have tended somewhat, in my judgment, to overfocus on financial capital and not sufficiently on human capital; human capital meaning mainly education and research, although health and child care are important contributions. In short, the cultivation of information and skills in a culture has a great bearing on economic growth and the well-being of the society. The research of the Schultz group of economists shows that very clearly. And, of course, there is no more vivid case than Japan. To overstate the matter, you can say Japan has practically nothing in the way of natural resources. Its great success is almost entirely a story of the cultivation of human resources, and I think it is important for us to bear that in mind.

Now, we have had a kind of reawakening, almost a rediscovery, of science education in this country in the past few years, with a spate of reports on the subject. I am glad, Mr. Chairman, that you alluded to the continuity of science education and the pipeline problem, and I want to underscore the talent pool problem.

As a matter of national interest, we have got to expand the talent pool. We are entering a situation in which the demography—and I am glad you said the OTA will be looking at the demography—the demography will mean we will have a smaller cohort of young people coming along, and within that cohort, a larger proportion will be minorities and, of course, women. Women have traditionally been, to a certain extent, taught inadvertently that they could not do science and technology; and many of the minorities, not all, have been in a worse situation than women in that respect. It is simply a talent pool we have got to take advantage of. We cannot afford, as a Nation, to waste large amounts of talent. It is a straightforward national interest proposition that we have got to do more with that talent pool, our whole talent pool.

Now, in my written statement, we have tried to cover to a certain extent the following topics. I will just state them rather than read them, and then I will say a word about the conclusions and recommendations. They are: Federal roles in science and mathematics education; the conditions, principles, and policies that have shaped Federal roles in programs; the general results of the Federal programs; and industry education programs, a booming business.

We also cover international features of science and mathematics education. In that context, I was very glad to see in yesterday's paper the administration's intention to strengthen international science education vis-a-vis Latin America. Another topic is the connections between all elements of our educational system, precollegiate as well as advanced science education.

Now let me turn to a few of the conclusions and recommendations and finish with that.

The Federal Government has played vitally important roles in science, mathematics, and engineering education, and really must continue to do so in the future. It is one place where the Federal Government, by, I think, anybody's standards, has a major and vital role.

Second, it is unfortunately the case in the nature of things that Federal attention waxes and wanes. Our attention as a people waxes and wanes. Crisis very often is the stimulus to action. It is important to have plans, at least contingency plans, ready to put forward at a time when we have a sense of crisis. It may be that we are close to that now with respect to education, and particularly science education. It may well be a time, in the next few years, when we can make important moves. It is very much worthwhile to take the longer time horizon rather than being preoccupied with one-time big fixes.

Third, it is extremely important that the Federal Government pay attention to the fundamental nature of the educational institutions, in this case referring mainly to the higher educational institutions. They are a very precious resource in many different ways, and the Federal Government is intimately bound up with the future of our institutions of higher education.

Since research and education are so intimately linked, that really does mean that virtually the entire spectrum of functions, particularly with research universities, are a matter of great concern to the Federal Government. I think we have to do a better job on the long-term follow through of activities such as your present study. There is a tendency for important studies, whether done in the Congress or the National Academy of Sciences or the AAAS or wherever, to sink without a trace a short time after their completion and become collectors' items, as it were, a few weeks after publication.

I think that would be tragedy in this case, and I hope that you will give attention to that but, more than that, that you will give attention to mechanisms, both governmental and nongovernmental mechanisms, for keeping attention focused on these matters.

The foundation for which I am responsible has recently set up a Council on Education and the Economy which is heavily concerned with science and technology education at the precollegiate level—other matters as well—and we have taken a decade-long timeframe, which is kind of shocking for foundations, which like to get in and get out fast—start something and hope that somebody else would pick it up—but our feeling is that unless strong institutions in society hang in there with major issues of the kind that you are considering, that they will tend to dry up and blow away. I do believe that, among other institutions, the OTA, to which you referred, Mr. Walgren, has probably an expanding role to play in matters of this kind.

Overall, we conclude that the system of science education and research in this country and the relationships between the Government and the scientific community are still very healthy—in fact, they are deeply admired throughout the world—but that when we come to looking at manpower questions, they ought to be put in the broad context of the health of science and technology in the country and not just in terms of sort of manpower machines.

The university-industry relations have considerable promise. They are discussed in our statement. We ought not to make bland assumptions about how far the university-industry relations can go in replacing Federal support. Not very far, probably. It is a very complex, promising set of relations; it deserves attention.

The talent pool point I have already emphasized. I want to reemphasize it. The level of fellowships and traineeships probably is not adequate for the needs of the future. This is especially acute in the behavioral and social sciences, and it is true at the earlier levels of science education more than at the later levels. But in general, we have lagged in focusing on the educational side of research careers and of science-based professional careers. It is a very complex picture, but overall, we need to be concerned about it, and therefore this particular set of hearings, I think, is most welcome.

Finally, we need to think in a worldwide perspective. The international dimension of science education requires a major reassessment. We need to think about long-term science and technology cooperation for developing countries. For instance, what happens in Africa after the famine? There is a lot that could happen. There are new patterns of scientific cooperation that could emerge that require, I think, the involvement of foreign students in this country; it involves our educating foreign students in their own countries; and a variety of innovations that could, I think, enhance the stature of this country worldwide, be in our own national interest, and utilize the demonstrable international character of the scientific community for humane purposes.

Thank you very much, Mr. Chairman.

[The prepared statement of Dr. Hamburg follows:]

Statement by

Dr. David A. Hamburg

Mr. Chairman and Members of the Task Force on Science Policy

INTRODUCTION

Thank you for the invitation to appear before you today as you begin your five-day series of hearings on "Scientists and Engineers: Supply and Demand." As I understand your purpose, in this part of the Government Science Policy Study you wish to examine the current and future set of relationships among the science and engineering education system, the manpower it produces and the workforce needs of the nation; and to examine what the Federal role should be.

More specifically, you asked me and Dr. Fechter to begin these hearings with an overview of the status of Federal programs for the support of science and engineering education and a review of past support programs. You noted, quite accurately, that in the forty years since the Bush Report, the Federal Government has supported advanced education in many ways through a variety of agencies and programs. Finally, you asked us to assist you in considering the effects — both positive and negative — of these government programs on science and engineering manpower.

After considering how best to respond to your request, both Dr. Fechter and I concluded that it would not be possible to provide a detailed evaluation and critique of the various programs which have been employed over the past four decades. Such an evaluation would be a large-scale, time-consuming, and expensive undertaking.

Having said what we cannot do, each of us, in somewhat different ways, will provide a number of overview comments and summary-type judgments on what has happened in science, mathematics and engineering education during the period in question. Incidentally, I will use an acronym, SME, for "science, mathematics and engineering" to reduce the repetiton of that long phrase. Also, each of us will identify certain conclusions and make some recommendations for you to consider. In my statement, I will approach today's hearings by examining the following topics:

- o Federal roles in SME education
- o Conditions, principles and policies which have shaped Federal roles and programs
- o General results of the Federal programs
- o Industry education programs
- o International features of SME education
- o Connectedness of all elements of our educational system
- o Conclusions and recommendations

Before proceeding with the main body of my statement, I would like to emphasize an important point which also was recognized in your published agenda: while this hearing and our statements will focus largely on graduate education, we need to keep in mind constantly the intricate and vital connectedness of all elements of the educational system — particularly with respect to science, mathematics and engineering education. What happens at the post-doctoral level is not separate and apart from what happens in elementary and secondary classrooms all over this land.

FEDERAL ROLES IN SCIENCE, MATHEMATICS AND ENGINEERING EDUCATION

Overview

First and foremost, the major premise for a prominent Federal role in SME education is closely connected to the basic reasons why the Federal Government has played such a major role in supporting research and development since World War II days. This connection applies particularly to the performance of that basic and applied research in the universities which is paid for by the Federal Government. You have addressed this overall Federal role and its rationale for supporting R&D on a large scale in earlier hearings so I will not discuss it here except as to how it relates to SME education.

An abiding article of faith — or perhaps it could be called a guiding principle — for the past four decades has been that the scientific and technological capabilities of the United States depend on the quality of the scientific and engineering education obtained by its students and on the numbers of students who enter scientific and engineering fields. On the other hand, the degree of commitment and level of attention to this principle has varied considerably over time. Among the results of this variability have been the following:

- Times of concentrated attention when education was at the center of national priorities in periods of crisis;
- Times of virtual neglect — sometimes benign, sometimes otherwise;
- A preoccupation with periodic "big one-time fix" solutions to perceived problems;

- Very limited attention — infrequent at that — to the shaping of long-term coherent strategies and the articulation of what objectives are to be pursued by the Federal Government;
- Ambivalence, as reflected in swings in prevailing policy views, on the part of national policymakers as to the division of responsibilities between the Federal Government and the States, between the Federal Government and the private sector, and between the the United States and other countries — especially Third World nations.

Nature of Universities and Colleges

In thinking further about the Federal roles in SME graduate education it is useful to take a look at the nature of universities and colleges as institutions. All universities and colleges share a common core of defining characteristics which distinguish them from other institutions. These characteristics arise from a set of values, traditions and goals which are essentially humane and altruistic; ultimately, it is these characteristics which have shaped the structures, provided the institutional stability, and established the centrality of the university in societies, such as our own, which are based on concepts of intellectual freedom.

Flowing from such ideas comes the role of the university as a center of trained intelligence dedicated to free inquiry, rigorous critical analysis in all fields, and the support of intellectual and creative activities as ends in themselves, quite apart from their utility. Yet, and nothwithstanding "ivory tower myths," another broad role of the university also embraces the commitment for the translation of knowledge and values in meeting the needs of the entire human community both through its graduates and in working directly with those in the wider world, includng the Federal Government.

A unique, general feature of most universities and many colleges in the United States is that these two broad roles are best performed when effective teaching and research are both considered essential. These functions cannot be considered as alternatives or choices. Productive research and scholarship informs and enriches teaching and is indispensable to the creative role of the university. Further, effective teaching is crucial to transmitting knowledge, informing research, developing good thinking processes, and preparing students for productive careers — not just a job. In short, teaching and research are closely intertwined. Our approach is quite in contrast with most other countries where teaching and research are largely separate, even in the large universities.

University "State of Health" and Change

The closeness and complexity of the relationships between research and teaching leads me to a major observation: I would voice a strong caution about considering the universities too narrowly as a "manpower machine" for producing scientists and engineers for the nation to meet a set of specific demands. Alternatively, I would urge taking a broader view of the "state of health" of the national science and technology enterprise of which academic R&D is a unique and vital part.

More directly and specifically, I think an integrated examination of the "state of health" of academic R&D should include, at the very least, levels of support for R&D and how the resources are distributed, the quality and availability of facilities, equipment and instrumentation and SME educational programs -- post-doctorate, graduate and undergraduate. And, beyond the "very least" level, I would add that the Federal Government cannot remain totally aloof from or oblivious to the precarious financial status of a large number of the colleges and universities of this country.

When college and university presidents gather these days, financial problems rank high on the list of priority topics. Reputable authorities such as George Keller suggest that the 3,100 American colleges and universities are now living through a revolution and that many will not survive it (Estimates of the number that will go under range from 10 to 30 percent by the Year 2000).

If this forecast range seems too drastic, consider this: despite a basic institutional stability of the large university for hundreds of years, U.S. history is replete with both evolutionary and revolutionary changes which have swept away many higher education institutions, required significant and substantial changes over time in the survivors, and created new types of institutions and functions.

And while there were many influences at work in these earlier changes, I would note that the Morrill Act of 1862 and other Federal policies helped accelerate and shape the revolution in education. Keller argues that the revolution now underway "is as profound a change as that which crushed the early nineteenth century world of tiny religious colleges and created the new era of universities, state land-grant colleges, graduate schools, coeducation, research, deans and postgraduate education for the professional classes at the turn of the century."

A more recent revolution in education swept the nation as part of the great expansion in the nation's scientific and technological enterprise that began during and after World War II — shaped in important ways by the principles set forth in the Bush and Steelman Reports. There was an even more rapid expansion in the post-Sputnik period when near-panic seized the country.

During this particular period of expansion, the Federal Government became the principal source of support for academic R&D and the ensuing rapid, dramatic increases in science and engineering departments, faculty for teaching and research, and students all over the country. For example, in pre-Sputnik days, the Federal Government provided not much more than one-half of academic support — with about 25 percent coming from Defense. After Sputnik, and until the mid-1960s, the Federal share rose steadily and sharply to more than 70 percent by 1966. Then the Federal share began to drift downward to about the 65-66 percent level today. Given this high level of Federal involvement, a related and obvious point is that the "ups, downs and plateaus" of overall Federal R&D funding have been important factors in the overall state of health of academic R&D.

As one element of the overall shifting patterns in Federal vis-a-vis private proportions of total national R&D, the private sector surpassed the Federal Government's share in 1979; the shares stand now — as they have for the past four years — at private (54 percent) and Federal Government (46 percent). One of the trends reflected in this overall pattern is likely to result in a continuing diminished share of academic research support on the part of the Federal Government to about the 60 percent level by 1990, with a commensurate increase on the part of industry — a feature I will come to later.

Graduate Students as Research Assistants

The relevance and importance of this discussion to your immediate hearings is that one of the more significant elements of graduate education in science, mathematics and engineering is their relationship to the levels, types and distribution of academic R&D. In the context of the close set of relationships between research and teaching discussed earlier, graduate students perform as research assistants on teams which perform research in the universities. However, good historical data on the numbers of such graduate students are simply not available in readily accessible form. Nevertheless, we know the numbers are large and that the services performed have been substantial; yet, in a numbers gathering sense, this form of Federal support is mostly "invisible." Overall, however, their numbers and contributions seem to be closely related to what happens to academic R&D in the aggregate and by the types of areas supported.

Various Other Federal Roles and Programs

Aside from the indirect support of graduate education through the support of academic research, more direct kinds of Federal involvement and interventions were part of the revolutionary changes in the entire world of education during the past forty years. These Federal roles have included providing direct tuition assistance, establishing large-scale loan guarantee programs, creating a variety of training grant and fellowship programs, establishing teacher training programs, creating new curriculum development activities, providing institutional grants, and intervening deeply into certain areas with a broad variety of measures.

One example of such an intervention has been medical education, my own field. The Federal Government has been directly involved in support of educational institutions, loans, scholarships, and grants to medical students. Indirect support has also been given through the financing of research and patient care. However, after a big build-up in the 1960's and 1970's, I should note there has been a substantial decline in overall government funding for direct and indirect support of medical education. This sharp decline has been due to fiscal pressures and a perception that the aggregate supply of physicians has increased to such an extent that it has become difficult to justify support to further increase the supply of physicians.

However, to jump somewhat ahead in the development of my outline for this hearing, I would suggest that what has been going on in the medical area may provide some general guidance on how to analyze these complex, interactive issues of supply and demand, research and teaching, and the overall quality and responsiveness of our health care system. In recent years, the medical communities have been carefully analyzing all facets of the system from the curricula in medical schools to the broad issues of meeting societal needs. I will return later to a few specific recommendations.

Many Federally initiated and supported activities affected SME education directly or indirectly, but the major focus — and the major share of the money — was directed at improving education in general. I need not dwell on the incalculable contributions made, for example, by the "GI Bill" education program which was shepherded through the Congress by a former Chairman of this Committee, "Tiger" Teague. And while many thousands of scientists, engineers and physicians have been launched on their career paths by that marvelous far-sighted piece of landmark legislation, I will now turn to those specific types of programs which affected SME graduate education more directly.

CONDITIONS, PRINCIPLES AND POLICIES WHICH SHAPED FEDERAL SUPPORT

Overview

It is regrettable but true that, all too often, we tend to do much of our policy shaping in an atmosphere of crisis or near crisis. Policy setting and establishing programs for or related to SME education have often taken place under such conditions. For example: Pushing through the GI Bill, establishing the NIH, the AEC, the Defense Department, and the NSF in the 1940s; enacting the rash of legislation in the post-Sputnik era for establishing agencies (e.g. NASA), raising budgets for R&D and SME education, and creating new programs in rapid order; putting into place during the 1960s an array of health care laws and programs; and, more recently, the pell-mell rush in the 1970s to create energy and environmental agencies, raise budgets, and programs.

The positive aspect of all this that we can act when the need is seen clearly and sharply; the negative is that at times we don't take the time to think through the problem and alternative solutions carefully enough.

Fortunately, we end up lucky with many of these rapid-fire policy decisions; but we end up with enough expensive mistakes to suggest that thinking somewhat more deeply about fundamental objectives and strategies could be helpful at times. Clearly, I am not talking about true emergencies; nor am I unaware of the problems we face in our pluralistic society of achieving consensus. And sometimes, "strike while the iron is hot" may be the only strategy that seems workable.

Actually, I am getting around to endorsing the measured approach you on the Task Force are following in your deliberations. I am hopeful that you will be successful in your attempt to zero in on those key strategic issues requiring intensive analysis.

As you penetrate the mass of material you are accumulating, I suggest you will be encountering a number of principles and policies which, if not in outright conflict, present inherent conditions of tension and tradeoff -- which, of course, is nothing new to you. In my statement I will cover, in varying degrees, the following areas:

- Egalitarianism vis-a-vis merit
- Another way of expressing the first point is geographical distribution vis-a-vis quality
- Still another way of expressing the first and second points is formula-type distributions versus need or quality
- Diversity of support versus concentration
- Support levels for R&D and SME versus other societal needs

- Selection of candidate areas for specific governmental intervention, including equity or target programs

Selected Specific Principles, Policies and Programs

GI Bill

The GI Bill rested firmly on the deep-seated strain of egalitarianism and open access which runs strongly through our political thinking, our institutions and our social structure — including education. Merit and capability were very much secondary considerations, and applied not to eligibility but to the student's place in the queue at some college or university. I have already referred to the unquestioned success of this program in bringing higher education to some millions of students who might not otherwise have had it. And in the process, the nation's attitude about access to higher education in general shifted toward it becoming more of a necessity. Further, the colleges and universities were themselves transformed and greatly enlarged in the process of responding to this massive Federal education program.

National Defense Education Act of 1958

Despite Korea and the Cold War, the nation settled into a period of relative tranquility and serenity with respect to our place in the world. There was a strong sense of achievement and satisfaction under a "Pax Eisenhower." During the early to mid-1950s, several attempts were made in Congress to obtain action on an Act for National Defense Scientific Scholarships and to establish a Federal Tuition Loan Guaranty Act. These proposals went nowhere — until Sputnik stunned the American people and the Congress. Initially, President Eisenhower was less impressed but eventually, to his credit, came to realize that a major threshold had been crossed over in human history and provided an extraordinary level of presidential leadership in dealing with the polictical crisis created by Sputnik.

In rapid order, a rash of legislative and presidential initiatives in response to Sputnik came to dominate the agenda for Congress in 1958. For example, in January 1958, the President called for a four-year,one-billion dollar (1958 dollars!) initiative to "stimulate science education and research." One outcome, among many (such as the creation of NASA), was the National Defense Education Act of 1958 which was — along the lines called for by the President — a four-year, $887 million program of student loans, fellowships, and other aids to improve scientific manpower resources. Also, an explicit purpose of the Act was to "improve science and mathematics instruction at all levels."

In contrast to the GI Bill, the NDEA had relatively little egalitarian flavor to it; merit and competition were much stronger components. In looking back, it seems clear that the NDEA led to the infusion of many thousands of new scientists and engineers — particularly at the graduate level — into the academic world and industry — which was what was intended. The Act was extended for a two-year period and then passed into history. It was a major example of a "one-time big fix."

National Science Foundation

Prior to Sputnik, the NSF had made some modest progress in carrying out its mandate for supporting basic research and science education — but modest is the operative word. Post-Sputnik, the NSF moved to a substantially higher plane of operations and budgets, with significant percentages of its total budget going to science and mathematics education. By 1970, for example, science education, at about $120 million, accounted for more than 25 percent of the total NSF budget of $460 million. I might add that, today, the NSF science education program is essentially in the "noise level" as far as the total budget of the agency is concerned (around 3 percent). Although, to be fair, as noted earlier, much graduate education takes place in the research supported by NSF, as it always has.

In any event, in the post-Sputnik years, NSF became a significant influence in a broad variety of science and mathematics education programs which ranged from the elementary schools through post-doctoral activities. A mixture of egalitarian and merit principles influenced NSF programs in varying degrees. At the precollege and undergraduate levels, there was a distinct attempt to raise up the general level of science and mathematics teaching and learning all over the country via summer institutes for college and high school teachers, through curriculum development for elementary and high schools, and by instructional equipment grants.

For its substantial and influential "portable" graduate fellowships, the ruling principle was competitive individual merit; those selected could take their fellowships to universities of their choice, based on mutual agreement. While there was — and is — a theoretical geographical distribution element present in the fellowship, both in the selection process and in where the awardees can go, the fact is that the winners tend to end up mostly at a relatively small number of the more outstanding research universities.

Even a casual review of the NSF graduate fellowship program (in various manifestations over the years) suggests that it has been a highly valuable investment in the nation's future. Simply looking at the subsequent records of former fellowship holders is one quick way to obtain a feel for the quality of the people selected over the years and what they have accomplished.

Yet, despite the fellowship programs overall success and its essential soundness, I need to raise an elusive and controversial aspect of this and other similar fellowship programs supported by the Federal Government. The very nature of the fellowship awards by disciplinary area and even sub-disciplines takes us to a discussion about the specialization vis-a-vis breadth principle noted earlier.

In a similar way to a basic problem we are now facing in medical education, for the future I think we need to give more attention to designing fellowship programs which, as a matter of policy, deliberately foster both specialization and breadth of training in scientists and engineers. Current — and past — programs may overly favor specialization at the expense of breadth and adaptability.

The former leads to early productivity in special areas of research; but today's state-of-the-art quickly becomes obsolescent in fast moving fields. Training and education which is too intensely focused on a narrow band of science or engineering may not prepare students to branch out into new areas of investigation. Breadth of training is needed to increase the ability of scientists and engineers to move quickly into adjacent fields as opportunities present themselves. More importantly, it perhaps can help produce individuals who are more than "scientific and technical experts" and can see their work in a broader perspective.

In this vein, it would be valuable to see at least some bold experimentation with curriculum development funding for institutions which might wish to test new forms of graduate education and fellowships in science and engineering. Such forms could, for example, put more emphasis on the societal and humanistic dimensions of SEM education. I suggest this with the full knowledge that such an idea is surrounded by controversy.

Before leaving NSF, it is worth noting that it pioneered a graduate traineeship program beginning in 1964 to provide supplementary support for engineering education. The program was based on the perception that engineers were in need of advanced training, since so few of them went on to obtain advanced degrees. Traineeship programs were and are designed to assist institutions rather than individuals; their undergirding principles are a combination of merit, need and geographical distribution.

NIH

Even before the NSF got into the training grant business, NIH had invented the concept for the biomedical fields during the late 1950s. The grants went to departments rather than to individual professors or researchers, although they were aimed at improving research training. As with the NSF training grants, the NIH training grants tended to be more spread out geographically than research grants, although the allocation decisions certainly involved some consideration of merit.

Now is as good a time as any to bring up another policy/principle issue -- although it really applies across-the-board, not just to NIH. I refer to the matter of diversity of support both for R&D and SME education. It is not my intention to dwell on this at any length, since you have previously looked into the fundamental strengths of our decentralized, pluralistic science and technology enterprise. My view is that concerted policy overview efforts should be made to ensure that the support of graduate and postdoctoral study in SEM education should come from a diverse array of Federal agencies — and non-Federal, for that matter.

Pursuing such a policy may be rather messy at times and difficult to follow. But it has the advantage of insuring that different criteria and viewpoints are taken into account. The various agencies, and various companies and industries, have different needs and motivations and will therefore different kinds of candidates. This is all to the good, I think, because I tie this concept of diversity back into the underlying strength of our entire social and political system, let alone our science and technology enterprise. Such an approach may very well create more difficult problems for those who prefer neat supply and demand models for manpower purposes under some kind of centralized control, but I think that would be the wrong way to go. I hasten to add that I am not against manpower planning, nor obtaining information about manpower in systematic ways, but I will return to this subject.

Specific Governmental Interventions

This is not a very precise term, but what is meant as I use it here is one or more policies and programs aimed at correcting or influencing a specific set of problems. Earlier, I described briefly the range of governmental interventions in the medical field. By the mid-1970s, various issues arising in part out of the civil rights movement had appeared in science and technology. Specifically, I am referring to the very low numbers of women, minorities and handicapped individuals in scientific and engineering fields. Policy debates over how best to correct the low representation and underutilization of such classes of individuals fall under the general ideas of "equity" and "targetting."

A number of specific programs such as "Women in Science" have been established during the past ten years. The results of these initiatives have been covered extensively in other hearings so I will not review them further except to make one major point. In the long run, the size and quality of the graduate students in science, mathematics and engineering depends on the quantity and quality of the "pool" from which they are drawn. Fellowship programs, no matter how generous, cannot make up for a lack of interest and preparation on the part of "pool members."

In earlier testimony, I have noted that demographic changes underway will mean that just to hold our own, we must attract a larger fraction of children than ever before into science, mathematics and engineering. One major way of doing this is to help insure that we bring more bright women, members of racial minorities and handicapped individuals into the "pool." This means engaging them and capturing their interest as early as elementary school and sticking with them through the entire process to post-doctoral programs. It is for this very reason that my own Foundation and others have joined with the Government to devote so much attention and resources to this area.

In another area, engineering research and teaching, the Federal Government is involved with industry and the universities in sorting out what kinds of policies and programs should be undertaken. While it does not seem likely that the types of broad intervention used in the medical field will occur, there clearly is a strong case for national action. This, too, is an area which has been covered elsewhere in hearings so I will not pursue it today, except to note later that the problems are critical and will not be solved completely by the marketplace.

RESULTS OF FEDERAL POLICIES AND PROGRAMS

Before proceeding to several other topics in science, mathematics and engineeing education I would now like to present a brief summary of what seems to have been the major results of Federal policies and programs during the past four decades.

o First, in a manpower sense, the aggregate results have been tremendously successful; large numbers of scientists, mathematicians, engineers, and physicians have been produced over the years. And, although there have been a number of cycles of either excess supply or demand, due in part to cycles in the economy, for the most part our national needs have been met. The major current exceptions to this situation are the following:

(1) Until the 1990s, it seems there will be shortages of computer-related professionals, particularly at the graduate level.

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(2) Critical shortages exist now, and will continue far into the future, for engineering graduate students and engineering faculty members.

(3) While in major fields such as chemistry and physics the overall manpower situation seems adequate, there are various subspecializations in which shortages exist.

o The response to Sputnik, rapid and massive, led to a large build-up in academic R&D during the 1960s -- in faculty size, graduate student output, departments of science and engineering, and research institutes. As just one measure of the magnitude of this buildup, in 1963 there were about 16,000 Federal fellowships and training grants; the comparable number for 1968 was about 51,000; by 1974, the total had fallen to about 18,000. By 1984, the number of such fellowships and training grants had declined further to less than 5,000.

o While the rapid, massive, Federally-inspired and supported build-up of the 1960s had the desired result of producing a substantially larger academic R&D world, as part of the larger buildup in our science and technology enterprise, it had some major negative consequences. Among these have been:

(1) A significant and worrisome age bulge in faculty members; the young entrants into the growing faculties of the 1960s are now 20-25 years older, and growing older in tenured positions in departments which are stable in size or declining.

(2) The implications of the age "bulge" are obvious in relation to the limited number of faculty openings for new, younger people,

except in computer science and engineering.

o In a more focused area of Federal policy, the results of programs directed at support of the super-bright, genius-level individual in the physical and natural sciences have been superb. An example of a recently-introduced program of this type at the NSF provides generous support for truly outstanding young scientists and engineers, and will focus on younger faculty members. Called the "Presidential Young Investigator Award," the program provides up to $100,000 per year for five years. During FY 1985 there will be about 100 awards.

o In contrast to the above program which is generous and far-sighted, opportunities for the remainder of graduate students and post-doctoral individuals have been very limited during the past decade or so. And it is important to note that it is from this population that will come the great majority of faculty members and researchers of the 1990s -- after the faculty "bulge" reaches retirement age in large numbers.

o Results of Federal policies and programs in the equity and "target population" areas noted earlier have been mildly encouraging, although much remains to be done. I testified in some detail on this matter before the Committee in February on the NSF Budget Authorization Request, and would only wish to emphasize at this time my view about the importance of keeping this set of issues high on your priority list.

o In concluding this section, I would like to observe that the Federal Government was a major actor in the creation of the "bulge" in academic R&D in the 1960s whose effects persist to this day. Federal policy can and does have major shaping effects, positive and negative, as you also have noted in your agenda paper. The results and benefits for the nation have been mostly beneficial, but the distortions in the universities have also been large. It seems reasonable that since the Federal Government has been a major beneficiary of the build-up it also should share in attempting to ameliorate the negative effects of the build-up distortions.

UNIVERSITY-INDUSTRY RELATIONS AND GRADUATE EDUCATION IN INDUSTRY

There are several other dimensions to SME education and academic R&D which may not seem at first glance to be related to the immediate concerns of your hearings. I will argue, however, that they are connected to the issues you are struggling with. One topic deals with what has come to be called "University-Industry Relations" and the other touches briefly on a rather new phenomenon, "Education in Industry."

University-Industry Relations

This subject has been on the congressional agenda for several years; likewise, the National Science Board has wrestled with it off and on for a very long time. However, until very recently there has not been much comprehensive information. To remedy this lack, the National Science Board commissioned a study which became the basis for its 1982 report, entitled University-Industry Relations:Selected Studies. In addition to the specific information collected, a major purpose and contribution was to provide a perspective on the current state of this set of important relations.

In the aggregate, only something in the range of the R&D performed by universities is supported by industry; as noted earlier, the Federal Government remains the dominant provider of funds which leads to the universities doing about one-half of the basic research performed in the united States. A closer look at this scene, however, suggests that industry is increasing its overall support of R&D at a faster rate than is the Federal Government. Based on several previous NSF-supported studies, this would generally indicate that industry will be increasing its support of university-performed R&D, especially basic research — although it must be underscored that the relative amount of applied research being done in universities is rising. Overall, there would seem to be a favorable climate for increased interactions between industry and the universities. For example:

o Restrictions on federal funding mechanisms are causing universities and scientists to look toward broadening their funding sources;

o A number of scientific fields are reaching a degree of maturity in which industry is able to recognize their potential for new business and for increasing productivity;

o Industry is expressing some degree of urgency and interest in, and the need for, specific kinds of scientific and technical people for new fields;

o University scientists are again beginning to look to some industrial laboratories as a way to gain access to frontier research equipment and scientific and technical advances.

As the NSB Report suggests, "The future paths for university/industry cooperation will depend on the way each university and corporation perceives the role of the university. Hence, it can be expected that many varieties of interactions will persist and develop."

But this is not simply a matter of industry providing more money to universities for research. While it is true that there seems to be growing opportunities for universities to work more closely with industry in research, in which the "university moves from satisfying wants to satisfying needs," a rather complicated partnership relationship emerges. And it is the nature of this partnership which calls for close attention as we look to the future.

Clearly, as the university moves into closer partnerships with industry, more resources can become available; but, as has happened to some extent in working with the Federal Government, the university inevitably relinquishes some of its unique capabilities for unrestricted exploratory research and freedom of action. But, as the NSB Report concludes, "There are no absolutes, and the issues become one of degree and common sense.... Too close a partnership with industry can be bad for long term growth, but too little can prevent the university from providing its optimum contribution."

Graduate Education in Industry

At the same time that industry seems to be moving closer to universities in terms of research, there are signs of divergence in the areas of teaching and learning. Indeed, in a very real sense, industry has become a strong competitor of the college and university world. The Carnegie Foundation for the Advancement of Teaching recently reported that "education and training by business has become a 'booming' sector of

American education as companies try to 'fill the gaps' left by inadequate schools and colleges."

The Carnegie Report, "Corporate Classrooms," notes that "most of the advanced corporate education programs were developed because nothing like them was available in regular colleges." For example, many of the corporate programs stress collaborative activities and group efforts while colleges and universities are so oriented to individual development that many students may not have learned to work with others.

And in areas related to advances in science and technology, colleges and universities must be concerned that many of the new corporate degree programs are in such areas. Indeed, technology itself is being used to extend the scope of corporate education, as pointed out by Neil P. Eurich, author of the Carnegie Report: Last fall, the National Technological University, based in Fort Collins, Colorado, began transmitting courses by satellite to corporate classrooms around the country.

Aside from the direct competitive threat presented to colleges and universities by the corporate educational programs -- particularly the programs granting masters and doctorate degrees in largely technical areas — there is a significant question of strategy faced by the educational institutions. How do they incorporate changes to improve their operations and offerings without falling into the trap of attempting simple imitation of what industry is doing — and thereby change their basic nature?

As a general concern, it would seem to me that colleges and universities must consider how to adapt to changing conditions — including the uses of new technologies — and yet retain those fundamental characteristics discussed earlier in my statement. My concern is related to a point made at the beginning: it would be a mistake for our country to begin to think of universities simply as "manpower machines." In this same vein, it would be a mistake for universities to become "job shops" for specific kinds of applied research and specific kinds of people desired by industry or government.

INTERNATIONAL DIMENSIONS

Special attention must be given to the growing foreign population in U.S. higher education as students and faculty. Such attention is in keeping with the growing internationalization of important sectors of U.S. life, the increasing significance of international business and trade, and the growing interrelatedness of nations and regions of the world. Our colleges and universities will necessarily play important roles in these trends.

It seems to me that the "internationalization" of SME education in the U.S. has served both our nation and the world as well. The record is clear that before World War II — and since — we have benefitted from the immigration of scientists from Europe and Asia who have ended up as researchers and teachers in our graduate institutions. In addition to their magnificent scientific contributions, they have helped to create today's generation of scientists and engineers. Later immigrants will help prepare the next generation. Federal policy should do nothing to discourage American universities from recruiting its science faculties and students from around the world.

There is, however, a very special problem which you have looked at in other hearings and I will only mention it in passing: the engineering faculty situation. The ratio of foreign faculty to U.S. faculty is probably higher than it ought to be in many colleges and universities; a particularly difficult facet of this problem is that in engineering schools, the faculty is largely engaged in undergraduate instruction. At this level, cultural and language problems can lead to severe instructional difficulties. Of course, the root of this problem is our failure to attract Americans into doctoral programs in engineering. I would emphasize what you have heard in previous hearings: this is a problem which requires Federal intervention along with the other efforts to deal with it being made by universities, foundations and industry.

I will turn now to another feature of the international scene: foreign students. During the early 1960s the Agency for International Development focused on institution-building and development of higher education opportunities. However, later in the 1960s and on into the 1970s, AID turned its focus to food production and the problems of the "poorest of the poor." I strongly believe that a major focus of U.S. aid programs and our foreign relations with the Third World should be shifted back to education.

Foreign-born students educated in U.S. universities are a precious resource whether or not they all return to their native lands. A vitally important "export" could very well be large numbers of educated individuals would urge that Federal policy and programs make it easier for the education of larger numbers of foreign students. Specifically, I suggest:

o Recruitment of more students from Third World countries by providing an extensive array of scholarships and fellowships to students other than those from the economic elites (merit basis); and

o Establish mechanisms and incentives to make it possible and desirable for young U.S. scientists and engineers to work in research and teaching in developing countries where they could help those countries build or strengthen their own educational and research capabilities.

CONCLUSIONS AND RECOMMENDATIONS

At this point I would like to make several brief comments in the form of what may best be called conclusions and recommendations. Although I hasten to say that I am not laying forth a specific plan of action. Indeed, I would be somewhat more comfortable with developing one or more of these suggestions in more complete form if you so wish.

(1) The Federal Government has played a number of vitally important roles in science, mathematics and engineering education and should continue to do so in the future.

(2) Unfortunately, but in the nature of things, Federal attention waxes and wanes -- with the onset of a crisis being the driver to action all too frequently. This leads to a major recommendation in the context of your study: the Federal Government should consider itself as an involved

partner in the educational system of this country — even though the system is highly decentralized. Further, a longer time horizon should be incorporated in strategic thinking about the Federal role — in contrast to the tendency to think in terms of "one-time big fixes" and then move on to something else.

(3) It is as important to the Federal Government as it is to the colleges and universities themselves that the fundamental nature of the educational institutions be preserved — in terms of intellectual freedom and independence. Further, the financial health of the educational world must be of concern to the Federal Government; it is not that the Federal Government should be viewed as a "savior," but neither can it remain aloof from or indifferent to the problems facing colleges and universities as many of them struggle for survival.

(4) It is important that we do a better job of following and analyzing the kinds of issues you are examining in these hearings. Continuity and stability are important considerations. I would urge that some thought be given to designing and establishing such a process. At the Carnegie Foundation we have thought one possible mechanism would be the creation of a long-term Commission on Education and Economic Progress. It is also possible that other kinds of approaches could be considered — in addition, not in lieu of such a Commission. For example, some kind of an expanded role for the National Science Foundation and the National Research Council's Office of Science and Engineering Personnel could be developed.

(5) Overall, it seems reasonable to conclude that the educational and

research system and the basic set of relationships maintained with the Federal Government are sound. The policies followed by the Federal Government over the past forty years have led to adequate supplies of manpower with few exceptions: engineering computer-related professions and some specializations in various sciences. Although manpower concerns are at the center of your attention in these hearings, I would urge that some caution be used in considering the universities too narrowly as a "manpower machine" for producing scientists and engineers. More specifically, I recommend taking a broder view of the "state of health" of the national science and technology enterprise of which academic R&D is a unique and vital part.

(6) In considering the manpower supply and demand subject, I think it is important to consider the possiblity that the basis for demand will change in the future as more organizations become technologically based. For example, Japan, with a population half that of the U.S., graduates and uses more engineers than do we. It is conveivable that over time our own usage of scientific and engineering manpower will be extendeo beyond the traditional requirements.

(7) The growing set of relationships between universities and industry are likely to become even more important in the future. This trend is of great significance and will inevitably affect the research role of the universities. What is important is that the universities not lose their independence in the process of adapting to future changes. Graduate education performed by industry is becoming an important element of the national educational scene. The issue here is related to my observation in

(5) above.

(8) Continuing attention needs to be given to the issues of equity and target populations in SME education.

(9) Consideration needs to be given to whether or not the present level of fellowships and traineeships is adequate considering future expected needs; my own view is that we are not supporting a program at sufficiently high levels.

(10) The growing international dimension of many of our most important functions and activities, including education, calls for new looks at this area. I strongly urge that consideration be given to a broad new set of educational initiatives in our assistance programs and relationships with Third World countries.

Thank you.

Mr. **Walgren**. Thank you very much, Dr. Hamburg. We appreciate that discourse.

Let's turn to Dr. Fechter, and then we will come back for some discussion.

STATEMENT OF DR. ALAN FECHTER, EXECUTIVE DIRECTOR, OFFICE OF SCIENTIFIC AND ENGINEERING PERSONNEL, NATIONAL RESEARCH COUNCIL, WASHINGTON, DC

Dr. **Fechter**. Thank you, Mr. Chairman.

I am delighted to be able to participate in the hearings of your Task Force on Science Policy. In the interest of brevity and time, I am going to read an excerpt of my prepared statement.

My task is to review the effectiveness of Federal programs for science and engineering graduate education and to explore how these programs, or any new programs, will provide the Nation with the human resources it needs to meet its future requirements. I am obliged to note that the views I portray in this appearance are my own personal and professional views, and they do not represent the views of the National Research Council or any of its affiliated organizations.

With that caveat made, let me point out that the topic I am to address is enormously complex. Moreover, the state of knowledge about it has been limited by the paucity of adequate and consistent data bases from which to derive rigorous inferences from past experiences. You should be aware, therefore, that in this brief statement, the treatment of this extraordinarily complicated issue will be quite limited.

I shall begin with a discussion of program goals and objectives, since any assessment of effectiveness must be based on these. I shall then describe briefly the experience of the past 25 years, focusing in on the very broad range of experience that Dr. Hamburg has just presented. This description will be followed by a discussion of program effectiveness. This presentation will conclude with some thoughts about future policy directions.

A wise person once told me that if I didn't know where I was going, any road would take me there. It is also true that without a clear understanding of program goals and objectives, one cannot evaluate the effectiveness of Federal programs under examination in this hearing and make decisions about future program directions. The objectives and goals of these programs are frequently based on a variety of rationales: alleviation of shortages, reward of merit, provision of equal opportunity. The ultimate objective that underlies each and every one of these, however, is and has been the assurance of an adequate national resource base for our science and engineering enterprise. These support programs aim to provide this assurance by enhancing, both qualitatively and quantitatively, the supply of human resources trained to engage in that enterprise. This objective can be and has been addressed by a multiple of mechanisms for the provision of such support: fellowships and traineeships, research assistantships, and need-based mechanisms such as student loans.

The experience with respect to fellowships, traineeships, and research assistantships can be likened to a roller coaster. Federal support of graduate students rose dramatically in the 1960's in the aftermath of Sputnik. These dramatic increases were followed by equally dramatic retrenchments in the early 1970's. The details of this roller coaster ride are summarized in my paper, and I will not go through them for you now.

Since 1975, the number of science and engineering graduate students receiving Federal support has continued to decline, but at a much slower pace. The continued decline in the number of students supported by Federal fellowships and traineeships has been offset in part by renewed growth in federally funded research assistantships, fueled by an increase in real federally funded R&D expenditures that has been experienced over this period.

This history may be summarized as follows, boiling down all of the statistics that I have looked at: the Federal Government probably supports considerably more graduate students in science and engineering now than it did in 1960, but program levels have experienced dramatic oscillations and support mechanisms have shifted, with fellowships and traineeships declining and research assistantships increasing in relative importance.

It is interesting to note, however, that compared with other sources of support, the Federal Government still plays only a minor role. Only one-fifth of science and engineering graduate students were primarily supported by Federal funds in 1983, while two-fifths were supported by State or institutional funds, and almost one-third were supported by their own sources of funds.

The task of assessing the effectiveness of these programs is, as noted earlier, a formidable one. Program effectiveness must be evaluated in the context of program goals. In the case of these programs, few would argue with an expression of these goals in terms of the adequacy of the human resource base for our science and engineering enterprise—indeed, Dr. Hamburg and I are on one course when it comes to that goal—although there may be some substantial debate about what the level of adequacy should be. Given this expression of goals, program effectiveness can be judged on the basis of an assessment of the following issues, and here I speak as a technician: How responsive has the supply of trained scientists and engineers been to variations in levels of program support? And how have levels of program support moved in a manner that would be consistent with the goal of adequacy described above?

The first issue, responsiveness, provides basic information about cost effectiveness; that is, the yield of scientists and engineers per dollar of program expenditure. Such information is useful in determining program mix. Clearly, resources should be concentrated on programs with high yields.

To determine these yields, one must be able to control for the effects of factors other than Federal support on graduate student enrollment and, ultimately, on science and engineering degree production, a difficult research issue. Moreover, there may be important qualitative interactions to consider. For example, a given increment in supply may be less effective if the supply of supporting resources, such as instrumentation and facilities, is inadequate.

In a similar vein, there may be important interrelationships to consider among the various sources of Federal support. For example, while fellowships and traineeships may provide support for part of the training required to complete a postgraduate degree, some additional support may be required from other sources. In this instance, effectiveness will depend on the availability of support from these other sources.

These analytic issues remain on the list of research yet to be accomplished. Their resolution is a necessary step for rational policy formulation with respect to Federal programs of graduate student support. This is a researcher's plea for more research.

We need more comprehensive information about sources of student support. We need a better understanding of the entire student support system. And we need to develop more precise estimates of the impact of these support programs on supply and on the performance of research. A cursory examination of existing data suggests that Ph.D. production probably was responsive to changes in the number of fellowships and traineeships supported by the Federal Government, although this responsiveness occurred with a lag of about 4 years. We know relatively little, however, about the impact of Federal support provided through R&D expenditures.

Addressing the second issue, the consistency of levels of program support with the goal of an adequate resource base, is an equally formidable task. The definition of adequacy, as noted earlier, is quite debatable. Moreover, Federal programs are but one of many factors that can impact on the supply of human resources, and a substantial number of these factors are beyond the control of Federal policy; for example, the size of the age cohort likely to be enrolled in graduate school, the attractiveness of job opportunities in nonscience or engineering careers, and the availability of support from non-Federal sources. Thus, determination of appropriate levels of Federal support must be done in the context of a particular definition of adequacy and under particular scenarios envisioned for these other critical determinants of supply.

An additional complication arises from the decentralized nature of decisionmaking in these programs. In the late 1970's, for example, the effect of the reduction in federally-supported fellowships and traineeships was offset in part by the impact of graduate student support of the expanding Federal R&D budget. In other words, research assistantships rose while traineeships and fellowships were declining. While the net effect may have been acceptable as a policy outcome, the lack of explicit means of coordination among the various Federal programs did not guarantee such a salutary event. Future policy must therefore provide mechanisms for effective coordination.

Despite the complexity and formidability involved in addressing these issues, some qualitative assessments are possible. The Federal programs have enhanced the supply of trained personnel. Trends in level of support have generally been consistent with stated policy goals with respect to adequacy, but lags that are inherent in the graduate training process may have resulted in changes that were too large in magnitude and too long in duration, particularly in the late 1960's and the early 1970's.

Now let me shift your attention from assessments of what has been the experience with these programs to future policy directions and judgments about what ought to be.

Starting from the present situation, the supply of trained personnel is, in my opinion, generally sufficient to meet the Nation's research requirements for the next 5 to 10 years, except maybe for spot shortages in areas such as computer specialties and some fields of engineering, particularly in the area of engineering faculty. I must also note parenthetically the problems that now exist in a related personnel area, precollege math and science teaching. These teachers are not directly involved in our research community, but they are an important component of the pipeline that feeds students to our graduate schools, and they ought not be ignored.

The situation expected beyond 10 years from now is less clear. A number of factors suggest a revival of demand, particularly in academia. Your committee is, I know, very concerned to get a good fix on what that revival of demand may look like. When combined with rising trends in industrial requirements for scientists and engineers with postgraduate training, this may create problems. Unfortunately, we are unable currently to forecast supply and demand that far ahead with sufficient precision to draw strong policy inferences.

Given the leadtime of 5 to 10 years required to produce Ph.D.'s in science and engineering, we need to substantially strengthen our capabilities to generate long-range projections for planning purposes. In the absence of a validated capability to generate such projections, Federal programs for supporting graduate students should not be used to eliminate particular skill shortages or to make quick fixes, as Dr. Hamburg noted earlier. Instead, particularly in the case of fellowships and traineeships, they should have as their aim the provision of the aggregate core of research scientists and engineers considered to be our essential long-range human resource base. This responsibility is probably best fulfilled by agencies primarily responsible for basic research—the National Science Foundation and the National Institutes of Health. Other requirements, particularly those related to the needs of mission agencies such as DOD and NASA, should be met primarily through the R&D budget. It is no accident that these prescriptions are reasonable approximations of the current system of support for graduate students. I believe that system has worked reasonably well in the past and is not in need of major overhaul.

Spot imbalances in skills should be managed, as they have been in the past, through mobility of experienced science and engineering personnel and through judicious use of postdoctoral appointments as vehicles for retraining or reorienting existing research skills. Judicious use of young investigator programs at research centers can also serve mission agency needs in the short run. Of course, this also implies that science and engineering graduate training should be of a kind that facilitates the type of mobility summarized above, an implication that can be used to justify graduate training that is general and easily transferable, and greater reliance on postdoctorate programs as extensions of graduate training. In addition, the focus on long-run research capacity objectives—as opposed to short-run manpower/skill shortage objectives—should argue for minimizing the type of instability that was experienced in the late 1960's and the early 1970's. Better planning can help smooth out these unnecessary peaks and valleys or at least minimize their adverse effects.

Finally, I believe there are compelling reasons for encouraging members of underrepresented groups to consider careers in science and engineering. Here again, I echo Dr. Hamburg's remarks. These constitute a potential pool of future graduate students, one that is expected to continue to grow in the future, in contrast to the non-minority pool, which is expected to decline. In the face of these contrasting demographics, an increasing share of our newly trained scientists and engineers will have to come from these groups, or from non-U.S. citizens, if we are to maintain or increase current levels of postgraduate degree production. I am particularly troubled by the current situation for racial/ethnic minorities. Gains in minority enrollments, both at the undergraduate and the graduate level, that were experienced in the 1970's appear to be eroding in the 1980's. It is not clear that the locus of programs designed to provide such encouragement to minorities to enter research careers in science and engineering should be concentrated at the graduate level. Recent analyses do suggest, however, that the leakage of minorities from the pipeline occurs at all levels of education, including graduate education.

Mr. Chairman, this concludes my formal presentation. I have tried in this brief statement to outline the goals and objectives of, and the historical experience with, Federal programs for science and engineering graduate education, and to describe the tremendous complexity involved in undertaking an assessment of their effectiveness.

I have also drawn on that experience and complexity to suggest future directions for research and for policy formulation. I shall be happy to respond to any questions.

[The prepared statement of Dr. Fechter follows:]

PREPARED STATEMENT OF ALAN FECHTER

Mr. Chairman, I am delighted to be able to participate in the hearings of your Task Force on Science Policy. The subject of this particular set of hearings, Scientists and Engineers' Supply and Demand, is an important one. These human resources are the heart of the science and technology enterprise of this nation and, as such, are precious. It is important, therefore, to assure that they are adequately trained and properly utilized.

My task is to review the effectiveness of federal programs for science and engineering graduate education and to explore how these programs, or any new programs, will provide the nation with the human resources it needs to meet its future requirements. The views I portray in this appearance are my personal and professional views, developed over the course of approximately seven years of exposure to and study of science and engineering personnel issues; they do not represent the views of the National Research Council or any of its affiliated organizations.

The topic is enormously complex. Moreover, the state of knowledge about it has been limited by the paucity of adequate and consistent data bases from which to derive rigorous inferences from past experiences. I have approached my task, therefore, with a considerable amount of trepidation. Nevertheless, some perspective about this important policy area is necessary as you attempt to grapple with how science policy decisions ought to be made over the next 40 years. You should be aware, however, that in this brief statement the treatment of this extraordinarily complicated issue will be quite limited.

I shall begin with a discussion of program goals and objectives since any assessment of effectiveness must be based on these. I shall then describe briefly the experience of the past 25 years. This description will be followed by a discussion of program effectiveness. My presentation will conclude with some thoughts about future policy directions.

Goals and Objectives

A wise person once told me that if I didn't know where I was going, any road would take me there. It is also true that without a clear understanding of program goals and objectives one cannot effectively evaluate the effectiveness of the federal programs under examination in this hearing and make decisions about future program directions. The objectives and goals of these programs are frequently based on manpower rationales, such as alleviation of shortages; merit rationales, such as the reward of talented students whose records of performance give promise of fruitful careers as research scholars; and rationales that call for the provision of opportunity to members of groups that are underrepresented in science and engineering. The ultimate objective that underlies each and every one of these, however, is--and has been--the assurance of an adequate national resource base for our science and engineering enterprise. These programs aim to provide this assurance by enhancing--both quantitatively and qualitatively--the supply of human resources trained to engage in that enterprise. This objective can be--and has been--addressed by a multitude of mechanisms for the provision of such support--merit based programs, such as fellowships and traineeships; service-related support programs, such as research assistantships; and need-based mechanisms, such as student loans.

Recent Experience

The experience with respect to the first two sets of programs--fellowships, traineeships and research assistantships--can be likened to a roller coaster. Federal support of graduate students rose dramatically in the 1960s in the aftermath of Sputnik. Existing fellowship and traineeship programs expanded in size; new programs, such as the NDEA fellowships, were created; and the number of students supported under research assistantships increased as federal R&D expenditures at colleges and universities more than tripled in constant dollars. In addition, a set of need-based work-study and student loan programs were established in the mid-1960s.

The dramatic increases in federal support of the 1960s were followed by an equally dramatic retrenchment in the early 1970s. The number of students supported by fellowships and traineeships declined by two-thirds from 36,000 in 1969 to 12,000 in 1974. The NDEA and NIH fellowship programs, along with the NSF traineeship program, were eliminated entirely. In addition, levels of support for the NSF fellowship program and the NIH traineeship programs were reduced significantly. The number of students supported by research assistantships fell slightly, reflecting the decline in real federal R&D expenditures at universities and colleges that occurred in the late 1960s and early 1970s.

Since 1975, the number of science and engineering graduate students receiving federal support has continued to decline, but at a much slower pace. The continued decline in the number of students supported by federal fellowships and traineeships has been offset, in part, by a renewed growth in federally-funded research assistantships, fueled by an increase in real federally-funded R&D expenditures that has been experienced over this period.

The history may be summarized as follows: The federal government probably supports considerably more graduate students in science and engineering now than it did in 1960, but program levels have experienced dramatic oscillations and support mechanisms have shifted, with fellowships and traineeships declining and research assistantships increasing in relative importance. It is interesting to note, however, that, compared with other sources of support, the federal government still plays only a minor role--only one-fifth of science and engineering graduate students were primarily supported by federal funds in 1983, while two-fifths were supported by state and institutional funds, and almost one-third were supported by their own sources of funds.

Program Effectiveness

The task of assessing the effectiveness of these programs is, as noted earlier, a formidable one. Program effectiveness must be evaluated in the context of program goals. In the case of these programs, few would argue with the expression of these goals provided earlier in terms of providing an adequate human resource base for our science and engineering enterprise (although there might be substantial debate over the definition of adequacy.) Given this expression of goals, program effectiveness can be judged on the basis of an assessment of the following issues:

How responsive has the supply of trained scientists and engineers been to variations in levels of program support?

Have levels of program support moved in a manner that would be consistent with the goal of adequacy cited above?

The first issue provides basic information about cost-effectiveness--i.e., the "yield" of scientists and engineers per dollar of program expenditure. Such information is useful in determining program mix. Clearly, resources should be concentrated on programs with relatively high "yields."

To address this issue, one must be able to control for the effect of factors other than federal support on graduate student enrollment and, ultimately, science and engineering degree production--a difficult research design issue. Moreover, there may be important qualitative interactions to consider. For example, a given increment in supply may be less effective when the supply of supporting resources, such as instrumentation and comparable other facilities, is inadequate. In a similar vein, there may be important interrelationships to consider among the various sources of federal support. For example, while fellowships and traineeships may support part of the training required to complete a postgraduate degree, some support may also be required from other sources. In this instance, the effectiveness of federal fellowships and traineeships will depend on the availability of support from these other sources. These issues remain on the list of research to be accomplished. Their resolution is a necessary step in the process of policy analysis and policy formulation with respect to federal programs of graduate student support. We need more comprehensive information about sources of student support; we need a better understanding of the entire student support system; we need to develop more precise estimates of the impact of these support programs on supply and on the performance of research. A cursory examination of existing data suggests that Ph.D. production may have been responsive to changes in the number of fellowships and traineeships supported by the federal government (although with a lag of about four years). We know relatively little about the impact of federal support provided through R&D expenditures.

Addressing the second issue--i.e., the consistency of levels of program support with the goal of an adequate resource base--is an equally formidable task. The definition of adequacy, as noted earlier, is debatable. Moreover, federal programs are but one of many possible factors that can impact on the supply of human resources, and a substantial number of these are beyond the control of federal policy--for example, the size of the age cohort likely to be enrolled in graduate school, the attractiveness of job opportunities in non-science or -engineering fields, and the availability of support from non-federal sources. Thus, determining how much federal support is enough must be done in the context of the particular definition of adequacy and the particular scenarios envisioned for these other critical determinants of supply.

An additional complication arises from the decentralized nature of decision-making in these programs. In the early 1970s, for example, the effect of the dramatic reduction in federally-supported fellowships and traineeships was offset, in part, by the impact on graduate student support of the expanding federal R&D budget. While the net effect may have been acceptable as a policy outcome, the lack of explicit means of coordination among the various federal programs did not guarantee such a salutory event. Future policy must, therefore, provide mechanisms for effective coordination.

Despite the complexity and formidability involved in addressing these issues, some overall qualitative assessment is possible. The federal programs have enhanced the supply of trained personnel. Trends in levels of support have generally been consistent with stated policy goals with respect to adequacy, but lags that are inherent in the graduate training process may have resulted in changes that may have been too large in magnitude and too long in duration--particularly in the late 1960s and early 1970s.

Future Policy Directions

Let me now shift your attention from a positive set of assessments of what has been the experience with these programs to a normative set of judgments regarding what ought to be. Starting from the present situation, the supply of trained personnel is probably sufficient to meet the nation's research requirements for the next 5-10 years--except maybe for spot shortages of computer specialists and engineering faculty. (I must note parenthetically, however, the problems that now exist--and will probably grow worse unless action is taken--in a related personnel area, precollege mathematics and science teaching. These human resources are not directly involved in our research community, but they are an important component of the pipeline that feeds students to our graduate programs.) The situation expected beyond 10 years from now is less clear. A number of factors suggest a revival of demand--particularly in academia. When combined with the rising trend in industrial requirements for scientists and engineers with postgraduate training that has been experienced in the recent past (and can be expected to continue in the future), this may create problems. Unfortunately, we are currently unable to forecast supply and demand that far ahead with sufficient precision to draw strong policy inferences. Given the lead time of 5-10 years required to produce a Ph.D. in science or engineering (and I include in that time some period of the undergraduate training to acquire the necessary math, science and engineering courses on which graduate training builds), we need to substantially strengthen our capabilities to generate long-range projections for planning purposes.

In the absence of a validated capability to generate such projections, federal programs for supporting graduate education should not be used as "manpower" programs--i.e., programs targetted to eliminate particular skill shortages. Instead, particularly in the case of fellowships and traineeships, they should have as their aim the provision of the aggregate core of research scientists and engineers considered to be our essential human resource base. This responsibility is probably best fulfilled by the agencies currently responsible for basic research--NSF and NIH. Other requirements-- particularly those related to the needs of mission agencies--should be met primarily through the R&D budget. It is no accident that these prescriptions are reasonable approximations of the current system of support graduate students. I believe that system has worked reasonably well in the past and is not in need of a major overhaul.

Spot imbalances should be, as they have been in the past, manageable through mobility of experienced personnel and through judicious use of postdoctoral appointments as vehicles for retraining or reorientation of existing research skills. Judicious use of young investigator programs and appointments at research centers can also serve mission agency needs in the short run without causing excessive imbalances. Of course, this also implies that science and engineering graduate training should be of a kind that facilitates the type of mobility summarized above--an implication that can be used to justify some effort in the graduate program to provide training that is general and easily transferable and greater reliance on postdoctorate programs as extensions of graduate training in the future. In addition, the focus on long-run core research capacity objectives (as opposed to short-run manpower/skill shortage objectives) should argue for minimizing the type of instability that was experienced in the late 1960s and early 1970s. Better planning can help smooth out these unnecessary peaks and valleys or, at least, minimize their adverse effects.

Finally, I believe that there are compelling reasons for encouraging members of underrepresented groups to consider careers in science and engineering. These groups constitute a potential source of future graduate students that is expected to continue to grow in the future (in contrast to the nonminority pool, which, in the near future, is expected to decline). In the face of these contrasting demographics, an increasing share of our newly-trained scientists and engineers will have to come from these groups, or from non-U.S. citizens, if we are to maintain or increase current levels of postgraduate-degree production. Particular attention needs to be given to the current situation for racial/ethnic minorities, in which gains in enrollments, both at the undergraduate and the graduate level experienced in the 1970s appear to be eroding in the 1980s in the face of an expanding pool of potential enrollees. It is not clear that the locus of programs designed to provide such encouragement should be concentrated at the graduate level. Recent analyses suggest, however, that leakage from the pipeline occurs at all levels of education (including graduate education).

Mr. Chairman, I have tried in this brief statement to outline the goals and objectives of and the historical experience with federal programs for science and engineering graduate education, and to describe the tremendous complexity involved in undertaking an assessment of the effectiveness of these programs. I have also drawn on that experience and complexity to suggest future directions for research and policy formulation. I shall be happy to respond to any questions.

PANEL 1 DISCUSSION

Mr. **Walgren**. Well, thank you very much, Dr. Fechter. We certainly appreciate the effort and the thought that lies behind that statement.

You both, as I understand it, direct us away from trying to address specific manpower needs through particular Federal programs and instead go toward this concept of health of the science enterprise, according to Dr. Hamburg, or the aggregate core of research that you focus on, Dr. Fechter.

Dr. Fechter, you indicate that those areas responsible for basic research would be the ones that you would like to see with the responsibility for that health factor or that adequacy factor. And yet the Defense Department is not generally considered as a basic research agency, and in fact falls out of that area, and yet we have consistently responded with essentially Defense Department as something that we throw in the breach of these problems, I suppose because there is instinctive political support for defense functions.

Do you see us being able to adequately support science in this health or adequacy function in areas or by mechanisms other than the Defense Department? Can I ask for general reaction to that?

Dr. **Fechter**. I will start.

I try to be very careful and say that the support should come primarily from the basic research agencies. I don't believe that we should necessarily be too rigid in dividing up the labor or the responsibilities with respect to support of our research enterprise.

I believe my statement of primarily basic research organizations is the right way to go. I am aware, for example, at the present time that both the Defense Department and NASA are considering programs of fellowships for graduate students. Clearly, if they feel, for their mission needs, over and above the basic research needs that are being supplied by the basic research agencies, that they want to play a role, I think it is perfectly appropriate for them to do so.

But again there, I would say that for mission agencies, the most appropriate way for them to play that role would be through their R&D budgets as they go to the universities and, through the R&D budgets, support of research assistants. However, I am not saying that specialization should be complete on either side.

Mr. **Walgren**. Dr. Hamburg, would you have any comments?

Dr. **Hamburg**. I would like to make a remark and also ask Dr. Wells to add something.

I think your point, Mr. Walgren, about the massive role of the Department of Defense in these matters from time to time throughout our history and certainly right now is a very pertinent one. If you look at the overall R&D budgets this year and the past few years, the real increase is in the military side. There is, for all practical purposes, no real increase in the nondefense part of R&D. So the aggregate figures on R&D seem to be booming, but that boom is on the military side, and therefore, I think there is a sense in which the Department of Defense has to meet an important share of the national responsibility for seeing to it that, in my terms, the health of science and technology generally is good.

I believe that it would be useful if, as a part of your inquiry, you look at the question of whether there are long-term, ongoing mechanisms to assess this health of the science and technology enterprise that include both defense and non-defense components, a truly national assessment. I have in mind major lines of advance in science and technology of the sort that the *Five-Year Outlook* was intended to address and sometimes has addressed, and I am not quite sure how vital an enterprise the *Five-Year Outlook* is now.

In principle, it seems to be very desirable that we ought to be kind of stretching our eyes to the limit and looking a little bit around corners to see what one can foresee this side of science fiction about major trends in science and technology, and then that will at least raise serious questions about probable changes in the economy that will come with foreseeable thrusts, particularly in the technological change, and that in turn will have implications for education at every level.

So the linkage of technology, economy, and education seems to me very important to be assessed. Now, indeed, there are even larger questions. The social dislocations that go with major technological and economic changes, who loses and who gains, and what kinds of problems--unemployment, where in the economy, and so on—I think we have to increase our capacity to anticipate by having mechanisms that are responsible for looking at those issues over the long term.

I mentioned in passing one that our foundation is trying to create. I do think the OTA has done very good work in this field and could have an enlarged function on a continuing basis. Another piece of it certainly has been through the National Research Council's various manpower studies. I know that in the biomedical and behavioral sciences, over a period of about a decade when I was familiar with that, the congressionally-mandated studies were the best we had available, I think anywhere in the world, to my knowledge, and with all the difficulties of manpower studies, they put them in the context of what was happening in those fields and what you could foresee would be happening and where opportunities would therefore emerge and what we were neglecting at a particular time or what we had overlooked.

So I think it is more important to come out of this set of hearings, really, with mechanisms that could work effectively over the long term, both in governmental and nongovernment low-cipher analyses of these questions, than it is to get kind of a cross section that in 1985 or in 1986, this is where we are and that is what we ought to do for the next couple of years.

Mr. WALGREN. Let me just ask, with the thought that we are looking for mechanisms that would focus us on that adequacy or that health of science, in looking back, how do you judge our success in addressing adequacy? Am I hearing that essentially our programs have been manpower, spot shortage, and sort of an attempt to assure adequacy simply by providing training through individual programs? Without a mechanism to assess adequacy, that is rather indirect, and so the degree of adequacy that you get is inadvertent as opposed to consciously sought.

So what I would like to ask is, looking back over the last 20 years, have we simply inadvertently become as adequate as we are?

How do you assess the degree of our focus on adequacy over the last 20 years? And are you asking us to really learn from that experience that we were not properly focused in those 20 years and that we should heighten the focus on adequacy?

Dr. **Hamburg.** My written statement tried to indicate that overall, as far as we can make out in AAAS, really, the Nation has come out pretty well. We have done it in a very pluralistic way, and I think we always will. We have not had a massive centralized planning apparatus that might have become rigid or monolithic or bigoted or whatever.

If one sector of the Nation was neglecting a certain issue, some other sector tended to compensate, and, in one way or another, we have, I think, come out pretty well on it. We have been, I think, fortunate to have very high quality leadership for some of our key institutions like the NIH and the NSF, and a very constructive relation with the Congress. Even though administrations would tend to go up and down and jump around a good deal, there has been a pretty consistent relationship. Particularly, the NIH has had, and, to a lesser extent but a significant extent, the long-term relationship with NSF and the Congress has been, I think, very helpful.

But there are problems with it—I will give you one—in terms of the overall health or adequacy of science and technology. I do not think, until a few years ago, that we had a strong concept in American industry generally, and particularly what we have come to call smokestack industry, that science and technology had an important role to play in improving product and process and enhancing productivity. So that was seen as something largely for high-tech industry, a kind of specialized branch quite different from all the rest.

I do believe that thinking persists to a certain extent, but less so today than even 5 years ago. I don't know that we really had a focus for looking at the relevance of science and technology for smokestack industry. I think we would be better off as a Nation if we had had a strong focus for looking into that in depth consistently over the past 20 or 30 years.

I was talking about this 20 years ago. There were sort of lone voices in the scientific community who were concerned about it and thought that we were giving insufficient attention, say, in the steel industry to the role that science and technology could play and, indeed, was already beginning to play in Japan and some other countries. But we did not have, as far as I know, a good way of organizing that kind of scrutiny, and it may be that some of the nongovernmental institutions like AAAS, should have taken more initiative in that period than we in fact did. But that would be an example of some gaps, even though, overall, I think we have an awfully good system. If it ain't broke, don't fix it. But still, there have been gaps.

Another example in the manpower field would be these big fluctuations about engineering. Do we have too many or too few? It was not so long ago that the conventional wisdom was that we had way too many engineers—we were in deep trouble—and now we are very worried that we don't have enough. It probably depends on what you are trying to do.

Right now the conventional wisdom in my own field, medicine, is that we have too many, we have to cut back, and there are some cogent arguments for that. But, you remember, for decades there was this concern about whether we had a shortage. Again, it partly depends on what your standards are, what your aspirations are.

But I think we have had a really hard time kind of putting engineering and medicine, the science-based professions, in the context of what we are trying to do as a Nation and the rapid changes in the world. Partly this becomes more salient just because I think the world is changing more rapidly than it has before.

Dr. **Wells**. A point that you raised, Mr. Chairman, about the past, and Dr. Hamburg's response that if one sector is dealing with the problem, others may step in later to deal, and it is not by an organized, overall plan.

A case in point might be, for example, in the midfifties, academic research was supported by the Federal Government at about the 50 percent level compared to about 65 percent that the Federal Government provides today. In the midfifties, half of that was provided by the Department of Defense. Twenty-five percent of the total academic research was DOD. Today it is down to about 10. NIH has become the big actor. But this didn't come from some grand design. It came from the way that agencies viewed their missions and viewed basic research changes over the years. Indeed, back in those midfifties, there are still people today in the university world who remember with nostalgia the great days of the early fifties when the DOD, particularly the Office of Naval Research, was one of the most generous, open-handed—less red tape, less bureaucracy as far as supporting basic science than any agency in Government today. So we have had these changes take place, but not because of design; it has been by many agency decisions and their own plans.

Mr. **Walgren**. Well, let me turn to Mr. Mineta, being that I used substantial time.

Mr. **Mineta**. I yield to Mr. Lujan.

Mr. **Walgren**. Mr. Mineta yields to you, Mr. Lujan.

Mr. **Lujan**. Oh, thank you.

I am sorry I was late and I don't know all of the things that were covered, except that I was reading over the testimony, and my question was, is most of the research money targeted toward postgraduate work rather than undergraduate work? Is there very little going into undergraduate work, and should we do something about that?

Dr. **Hamburg**. I am very glad you raised that.

Mr. **Lujan**. And how, probably.

Dr. **Hamburg**. There is an awful lot of research training built into the normal research grant process. An experienced investigator, a person who has conducted research for many years—I know from my own experience—is very delighted to have postdoctoral fellows or graduate students. Whether they are labeled as fellows or not doesn't matter; if you've got them, you can put them on your research grant. They work very hard; they are smart; they want to get out research. And so it is very productive, and in the process, one hopes they are getting research training, and no doubt they do. I mean, if they are in a good environment, you cannot stop them from learning how to do research, and with a modicum of attention from the senior people, it is a very stimulating mutual-benefit kind of situation. So a lot of our research training is, in a sense, hidden in the research budgets. It is not intended as training money, but it really, in part, amounts to that.

We have been going more and more in that direction in recent years, I think, and partly the effect that has is to lead us to forget a little bit about the people at the earlier levels. How do you bring the, say, college student into that picture, let alone the precollegiate? And, after all, the intellectual curiosity for science starts very early, very early. I would put a lot of emphasis on the pipeline phenomenon. So I would say the earlier, the further back you go, the more there is slippage in this system, because it is the more advanced people who are ready to be productive in research and get their advanced research training through participation in the research grants.

The other thing is an aside, but a non-trivial aside, I think, and that is that in the science-based professions—and here I know more about medicine, some about engineering, and I am not sure about the agricultural part—but certainly in medicine and in engineering, there is some slippage on the scientific training for some fraction of doctors of engineers who want to be scientists. I mean, most of them will be practitioners, will be using the science; they will be consumers of science. But you do want a significant proportion of doctors and engineers to do advanced work and to be at the scientific cutting edge in the field and the people who connect with the basic science, and they tend to slip out of this net.

Well, for one thing, just in practical terms, I remember my colleagues at Stanford Medical School saying to me, well, to have a medical student working in the lab, even if he is just as smart as a Ph.D. candidate or a postdoc, is not as good from my point of view. He doesn't have as much time available; he has other considerations; he has got to see patients, and so on.

So what I am saying is, basically, that you have touched on a kind of slippage in the system where it is the advanced, more or less full-time research young person who gets the benefit of research training through the research grants, and other categories tend to lose something. It is a very important point.

Mr. LUJAN. Let me follow up a little bit, and maybe you might address that. One of the things I noticed as I was reading your testimony, Dr. Hamburg, you mentioned women in science. Is that the way to increase the number of people going into sciences, to target, then, specific groups because maybe there is more activity, to get more women, more minorities, more people over 6 feet or under 6 feet or whatever category you wish to choose? Is that a good avenue to pursue?

Dr. HAMBURG. My belief is that, A, it is important to start very early. Well, first, let me say I am not talking about—what shall I say?—an honorary degree. I am not talking about passing through women or minorities who haven't done good quality work because you want to increase the numbers.

Mr. LUJAN. No, I meant taking them out of high school and moving in that direction.

Dr. HAMBURG. Putting them on a basis with everybody else. You have to take into account—in general, you try to do it in education on an individual basis—to take into account what kind of particular deficits or handicaps have existed before. If a student comes into a life sciences program and has had no mathematics, you have to ask yourself, well, do we have to take a little time out for some special effort to get at least a decent minimum of mathematics to cope with what we are doing in the life sciences? Well, so, too, with women; there is a certain amount of, I think, special and distinctive work at least to get them up over the threshold of the kind of pall of discouragement that they have traditionally had, particularly about mathematics and physical sciences and, to a somewhat lesser extent, about life sciences and behavioral sciences. We have seen a big change in that. For example, the medical schools, which had, when I was a student, I don't know, about 3 or 4 percent women, today have nearly half, and they do very well. I mean, they are doing just as well as the men if not better. So the old pall of gloom about women, I think, will rapidly dissipate.

I think it is a tougher problem where you are dealing with very poor minorities, and minorities have been subject to social depreciation over a period of time, where there are a lot of smashed families in smashed communities— I know I am overstating it, but deliberately to make the point that these kids tend to be easily scared off from science and technology, feeling that they cannot do it; it is too difficult, and so on. The issues of incentive and motivation and encouragement become very important early, and here we are really talking about even elementary school and certainly secondary school. I think that is a crucial part of the national need, to take advantage of that talent pool in the years to come.

Dr. FECHTER. I would agree 100 percent with Dr. Hamburg's remarks and just simply point out a number of things. One is that the pool of potential scientists really peaks, in terms of a life cycle, at the midschool level, junior high school level. After that, the net flow in terms of interest is out. This outflow is particularly strong for both women and for minorities.

I think we do have reasons for targeting at all levels, I believe, and particularly for minorities, as I said in my testimony, because we see this outflow, this attrition, from the pipeline taking place at every level of education and training.

I believe, however, that it is very important—and I am not sure whether it is the science policy issue that we are to address this with—that it is very important to address the pipeline issue early on, and I think the undergraduate level is an important level, where the combination of education-oriented versus science-oriented mix of policies becomes very critical. I think there needs to be some thought given to more focus of resources in preparing students for science careers at the undergraduate level than now exists.

Mr. LUJAN. What I gather from that is that we should have an emphasis of peaking kids' interest maybe in junior high.

Dr. FECHTER. Yes.

Mr. LUJAN. You are saying that we should have some kind of program because by the time they get into college, why, they have a fair idea of where they are going.

Dr. FECHTER. I might add one more point from the research I have been looking at lately. It was rather dramatic, and I would

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share it with you. That is that if you look at continuation rates and career achievement rates, particularly continuation rates into science careers, at the graduate level, and you look at disparities across race/ethnic groups, they are considerable, as you would imagine. But if you standardize these continuation rates for family background characteristics and, in particular, if you look at the role of whether or not one parent had at least 1 year of college, you find that the disparities virtually disappear; they virtually are wiped out. So I guess what I am saying is that there is a feedback mechanism that one has to consider. One has to have parents and role models who are already in the community to which these young people who are at the middle-school level can aspire and take as their models.

Mr. LUJAN. No question about that. Having established that we have to do it at that lower level, as far down as we possibly can, my question was directed at, should our programs be directed at the population in general—certainly, yes—with specific targeting to groups so that there is competition and maybe accountability on the part of the recruiters or whatever? Do you find in your experience that those kinds of targeting strategies are beneficial or even acceptable?

Dr. FECHTER. Well, I speak as one who is administering a number of programs that are targeted to minorities, so you may take my remarks for what they are worth under those circumstances. I believe the answer is yes. I believe that aside from the overarching principle of equality of opportunity that is implicit in a targeting mechanism, I think there is a need to equalize the opportunity. If we do not equalize opportunity, I believe we lose people—they attrit—and that loss is a loss to all of society, and the Federal Government must play a role to make sure that those social costs are minimized. I think we must play that role.

The other side of that is, I don't think that the equality of opportunity by itself should be what governs totally the policy formulation, how much we support, how far we go. I think it has to be put in the context of our overall science needs. If we are talking science policy, I think there is a legitimate role for targeting on minorities to bring them into science and engineering. But the overall focus should be on the science and engineering needs and not on the needs of equal opportunity.

Mr. LUJAN. Absolutely, and I wasn't referring to the social needs or the social policies.

Dr. FECHTER. Right.

Mr. LUJAN. It is strictly a matter of getting more young people to come into science and engineering.

Dr. FECHTER. In my opinion, if we are to maintain our science and engineering resource base, human resource base, we must focus on those minorities and other underrepresented groups such as the women.

Mr. LUJAN. I was looking at the competition amongst groups, you know. Hey, you've got more women, you've got more minorities, so I'm going to catch up with you, so I'm going to get some more, without lowering the standards.

I am sorry to have taken so much time here.

Mr. **Mineta** [as acting chairman]. Thank you very much, Mr. Lujan.

I appreciate both of you being here today, and I especially want to thank Dr. Hamburg because I happen to be the beneficiary of a congressional fellowship that is being sponsored by AAAS, and we have a Ph.D. in biochemistry in our office for a good period of the time, for which I thank you very, very much.

Let me ask whether or not, in this whole field, we are eating our own seed corn in that we are seeing a lot of people leave the academic field to go into industry. We also see that those who are staying behind are being helped by Ph.D.'s who are in nontenured positions, so they never get into the tenure track. I am wondering whether or not this is hurting the whole graduate school program at the university level.

Dr. **Hamburg**. Yes; first, let me say that we are very pleased that you have had Dr. Correra-Freire with you, and we feel just as good about it as you do. She is an outstanding person.

I think you have put your finger on a very important issue. We do briefly try to address it in the prepared statement. We have this kind of bulge that went on in the early sixties when there was this expansion of opportunity in the university faculties. I remember vividly, I was a beneficiary of it. I was building a new and innovative department at Stanford Medical School at that time, and I was able to recruit people right, left, and center because we had so much Federal funding. We used to talk about Stanford Medical School as NIH West at that time. We never would have been so bold—and I think maybe even pretty successful about what we did—if it hadn't been for that explosion of Federal support.

What that did was to bring a lot of outstanding people to the tenure track positions then, and before long they had tenure, and now that school, like so many others, is, in a way, clogged up in terms of tenure openings. They are more in computer science and in some fields of engineering, but in general, it is very hard for a young person to think about getting tenure.

Now, as I look at that situation, one thing that has happened has been that a lot of excellent people who would have like to stay at Stanford in a tenured position have gotten tenured positions in other universities which are also very good and have become better as a consequence of the spinoffs from the Stanford's and the MIT's and the Harvard's, and so forth.

But there is also a limited absorptive capacity, and you get to a point where you have to ask, are we going to sort of go under water for a number of years before we create new opportunities, or are we going to make some special effort to even this thing out so that you can have new opportunities and not have perhaps an undermining of morale and a withering of institutional capability?

I think it is a very serious policy question right now, and if you meet with, say, university presidents or deans of science faculties and the like right now, it is one of the main subjects on their agenda: What are they going to do to open up some opportunities for young people? They are talking about early retirement, all the options that are open to them. But I do think it is a serious question for national policy right now. I am glad you raised it.

Dr. FECHTER. Yes; it is. Most of the eating of seed corn that you referred to, I think, I see most vividly in fields like engineering, where many of the new Ph.D. graduates, the few that we get who are native-born U.S. citizen graduates, are moving into industry, and they are drawn there by a number of factors. The research opportunities in general, with the equipment that industry has to offer is a very important factor, I think, in many of these decisions.

I think the issue is as Dr. Hamburg has expressed it, which is that we have what some people have referred to as "the pig and the python" phenomenon, where that very rapid buildup that took place in the sixties of individuals who got tenured positions in academia are now going through the system and are approaching the ends of their careers. The ends of their careers will occur in about, I would say, 10 years, roughly speaking, the midnineties, and they will begin to exit at that time.

But in the meantime, there is this tenured-in effect. There are very few tenure track openings developing, and what you are getting, if you look at the numbers, is a very large increase in the number of what is called nontenure track research positions being filled in the academic sector.

I know that there is a particular ethical problem that exists among some of the medical schools, for example, where biological scientists have been on soft money, and many of them have been on soft money for maybe 10 years. If, in fact, the money that supports these biological scientists and life scientists dries up, if NIH were to disappear tomorrow, for example, there is an ethical question about what the university's commitment would be to these people, since they don't have the tenure and the purposes that go with tenure.

The answer to what do we do about it, I think, has a number of facets. There are the short-run measures that Dr. Hamburg referred to. Universities are looking to policies to encourage early retirement, and indeed, I think this committee would do well to look at the New York experience with respect to this. At the current time, New York State, the State system, is offering very generous packages to older professors to retire early. They are giving them a larger fraction of their incomes as their pension rights. We don't know yet what the effect is going to be, how many people will take advantage and will leave the system, but I think that is a short-run fix to the problem. Indeed, that is all we can look to right now to do that. The longer-run problem, I think, is how does one smooth out?

We have built in this cycle for several generations to come. We have a situation where there are very few tenure track openings now. Ten to fifteen years from now, we are going to have another large increase in job opportunities in academia as these professors retire and as the second wave of the baby boom begins to start hitting the universities. About 15 years thereafter, I am sure we will have another situation of limited opportunities for tenure again. So I think it is important that this committee consider the question of how, in the long run, do we take measures that will smooth out these very extreme fluctuations we have been encountering in the past.

Mr. **Mineta**. Now, as they go through this system of encouragement of early retirement, what encouragement is there to bring young people in? I was talking to the head of our chemistry department at San Jose State University, who is out recruiting right now for this coming September for an assistant professorship, Ph.D., minimum 2 years experience, offering $22,160. Now, who in their right mind with a Ph.D. in chemistry and 2 years of experience is going to become an assistant professor at San Jose State University at $22,160? So you may get early retirement on one hand, but on the other hand, if you cannot encourage people to fill that sort who are academically qualified and have the incentive to become part of academe, where are we?

Dr. **Fechter**. That is the quintessential problem, I think, that we have a situation in which the current market may be affecting people's decisions about whether they go on for Ph.D.'s, and if they do go on for Ph.D.'s, whether they want to pursue their careers in academia or in industry, where the rewards are larger. We may be in a situation where the current disincentives will impact in ways that will hurt us very badly 5 and 10 years down the road. I am more worried, I think, about the students who are freshmen in colleges now or somewhere between freshmen and onto their baccalaureates, who are making decisions about what courses to take and what careers to pursue, and who are making these decisions against science, against research careers. They are moving into nonresearch careers.

Business administration is a very important field, and engineering, but not the graduate-level engineering. It is the baccalaureate-level engineering fields that are the popular fields for the undergraduates today. If in fact we think we are going to need lots more Ph.D.'s to fill faculty openings and to fill the jobs that industry is increasingly requiring of Ph.D.'s today, we may have a real problem down the road.

Mr. **Mineta**. Let me just play devil's advocate for a moment. In reading or at least listening to your paper, Dr. Fechter, I am wondering if there isn't an Orwellian tinge to it in the sense of trying to do some planning to get us to whatever those objectives might be. But I am wondering whether or not we are not where we are today because of the, quote, planning, unquote, that went on 20 years ago, and someone had to pick the winners and losers, and now we are where we are.

Dr. **Fechter**. I would respond first by saying that it is now 1985, not 1984; therefore, I did not mean to be Orwellian. It is past that time. But, more fundamentally, I think I would respond by saying that the reactions that took place 10 and 15 years ago, I think, were reactions which were short run, and I don't mean in a pejorative sense shortsighted, but shortsighted. They were responses to existing needs at that time.

I think there was a failure to think in the longer run, and that is what has been the problem. The problem is that we have to be thinking now about what we want to see 10 and 15 years from now in terms of what is coming out of the pipeline with respect to scientists and engineers for research careers, because it takes that long to get the supply. It is almost like turning an aircraft carrier. It just takes a long time to turn the supply decisions around because there is such a long leadtime in the training.

My point is that I don't believe we will ever get to the point where we can fine tune our production of Ph.D.'s to the point where we can exactly meet what we need in each field. My preference would be that we at least think ahead and that we take the kinds of steps necessary so we get some idea of what the scenarios generally will look like out there 10 and 15 years from now and provide an aggregate and a base of human resources that, in the aggregate, will be large enough and also will be flexible enough in terms of their training so that if they don't quite match what is at that time the need for their skills, they can be retooled very quickly.

Mr. **Mineta**. Dr. Hamburg, I was interested, on page 9 of your statement, about the implication about the surplus of physicians, and I am wondering, if there is that surplus, has it manifested itself in some positive manner, so to speak, in the marketplace? Have health-care costs come down? Is accessibility to a physician or a specialty area better for me as a patient today than it was 10 years ago?

Dr. **Hamburg**. Well, let me say this, I guess, as a value proposition: If you have to make a mistake, I would rather have too many than too few.

Mr. **Mineta**. Now, how you define the word "surplus"?

Dr. **Hamburg**. Well, the main argument about the surplus really had to do with health-care costs, as you identified. It really wasn't a question of some kind of science-based ratio of physicians to populations but rather that the health-care costs kept going up for a long time and more or less doubled the general inflation rate, and that was very alarming. People did not see the supply and demand coming into effect. You would normally hope that you would get to a point where you would have more doctors and costs would begin coming down, prices would diminish, and all that.

However, there was a certain amount of evidence that the more doctors you have, the more procedures are done, and the more costs go up, kind of a self-generated demand in a system where the decision was very largely the doctor's to make, where there was really a tremendous disequilibrium between the buyer and the seller, as it were, and if the doctor said do it, you would do it, and procedures were reimbursed in a more or less open-ended way. In that system which we have had, there has been a certain amount of empirical evidence: the more surgeons, the more surgery; the more doctors, the more procedures; and the costs escalating seemingly endlessly, although, mind you, there were evidences of real health benefits from all, maybe not health benefits commensurate with the investment—that is a hard argument to make—but at any rate, there were health benefits.

Now, a lot of that depends on the reimbursement system. In the last couple of years, we are seeing a response of the payers, of industry, and the beginnings of response from insurance companies; and, of course, the changes in the reimbursement patterns of the Federal Government, a set of changes basically bumping up against the kind of outer limits of what could be tolerated, at least for the time being, in health-care costs. If health-care costs rise at a more moderate rate, that whole question about the sufficiency of physicians may look different. It also depends on how seriously you take the availability of physicians in the inner cities and in rural areas. If that is an important concern, then we are not home yet.

Mr. MINETA. Is that a case of maldistribution rather than surplus?

Dr. HAMBURG. Absolutely, maldistribution, if you are concerned about the health of the whole population. I mean, you look at our black-white differentials still, and it is staggering.

Mr. MINETA. Is it geographical maldistribution as well as by specialty?

Dr. HAMBURG. It is geographical and by specialty, in my judgment, and all of that involving a maldistribution with respect to the income of—15 percent of the people in this country still have no health insurance whatsoever.

Mr. MINETA. So can we call that a surplus?

Dr. HAMBURG. I am not impressed by the surplus arguments. I mean, I have to say that I think, on health-care costs, we are up against a very tough problem. Why? The changing age composition of the population. As you have a larger and larger proportion of older people, you will have more difficulties, and one way or another, you will have a greater demand, a greater legitimate demand, in my view, for care.

Second, you have the greater intensity of health care as the technology advances. Now, there may well be, as in the computer field, that in due course the technology will bring down the cost of various diagnostic, therapeutic, and preventive interventions. Of course, it is a lot cheaper to prevent polio with a Salk or Sabin vaccine than it was to treat polio patients, as I did for some years. But still, many of the technologies in their early years raise costs rather than lower them, so you have this high intensity of care and an older population, and those are factors pushing health-care costs; very difficult to cope with.

Still, it is pretty clear that you cannot have just an open-ended reimbursement, sort of a cost-plus system of one kind or another, for hospitals or for doctors, and the latter is something we are coming to terms with. But it does seem to me that even with all the health care cost problems, it is very difficult to talk about a surplus when you are really talking about maldistribution and a great deal of health care opportunity being missed in the society. But if you are worried about that, you have got to address that explicitly, and I confess that I think that in the past few years, we have paid, as a society, very little attention to the maldistribution issue.

Dr. FECHTER. I would like to simply reinforce Dr. Hamburg's earlier statement that, in medicine, supply creates demand, and that is to say that as you get an increase in the supply of certain kinds of medical persons and they begin to recommend certain kinds of medical procedures, the demand automatically goes up, so there is almost never a surplus sort of shortage. It just operates almost a self-equilibration.

But I think that there is an element in the pipeline which I would simply want to lay on the table for the committee to consider, and that is that in recent years, applications to medical schools have been showing a downward trend. Now, to the extent that these students are well informed about market conditions and career opportunities, they are saying something by their career choices.

Mr. **Mineta**. Without going down a tangent, I suppose one thing about medicine is that unlike, let's say, manufacturing a widget, as you improve medicine, costs go up. If you improve the production of a widget, chances are costs go down. But in the field of medicine, probably costs go up. Ten years ago we did not have the dialysis or CAT scan, et cetera.

Second, I suppose a lot more defensive medicine is being practiced today rather than improved technology, just because of the malpractice suits involved. At least my brother, who is an M.D., tells me, as an insurance broker, about his increasing malpractice liability insurance premiums. So I can see that we are getting ourselves in that kind of a bag.

Let me ask—because, Dr. Hamburg, you commented on the university-industry relationship as it relates to research, and then you mentioned that in the long term, a close relationship may not be a healthy relationship, and I am wondering, given our Federal budget deficit situation, what would you do to try to increase the kind of participation or contribution that industry might make, the private sector might make, to the university as far as research is concerned?

Dr. **Hamburg**. It is certainly increasing, and there is a lot that is very striking about it. In or near your home district, the relationship that Stanford has established both in the biotechnology field and the electronics field are really at the cutting edge, some very imaginative arrangements in that respect, rather bold.

I think, on the whole, it is very invigorating. One thing it does is to get you this dynamic interplay between basic and applied research that I refer to in the case of DNA as genetic material and pneumonia and all that—and there are many examples that could be given—and if anything, the time between basic discovery and at least plausible application is shorter now than it has ever been in many fields; certainly in the life sciences, that is true.

So there is a lot to be said for having a situation that sort of rubs the noses of basic researchers of great stature in applied possibilities. In my view, almost all of the basic scientists I have known are sort of closet humanitarians; they like to see something useful done with their discoveries, although if you ask them straight out, like in a committee hearing, they will deny it and say art for art's sake, science is important, and it is, of course.

But I think that kind of interplay between basic and applied has fundamental value and is very stimulating for all concerned. But I am rather skeptical of the extent to which industry will support basic research at the universities for the long term, and my skepticism is based on a very straightforward appraisal; that is, asking a number of leaders in the pharmaceutical and chemical industries vis-a-vis biotechnology, what do you expect?

I think, in general, if you have them up here to testify, they will tell you, do not count on us for long-term major support of basic science. They will tell you, if the Federal Government doesn't do that, there is not going to be very much of it.

Now, that could be wrong. But they want to have access to very good basic science, and they are willing to pay for a certain amount of it, but they feel that basic science by its very nature is a very long-term investment, a very chancy investment, and that they cannot afford to go very far down that road, especially with our industry having a kind of short timeframe as it tends to have. What is the next quarter's bottom line going to look like? That has to be viewed with some caution.

Some of the industries looking at biotechnology, for example, are making a decision whether or not to develop the capacity in-house. There is a considerable preference in a number of the companies to build a big in-house capacity if they think it is really worth doing.

Mr. **Mineta**. Let me ask, are we putting, then, from the Federal perspective, too much money into applied research and not enough into basic, and let the private sector pick up on the applied research side of it?

Dr. **Hamburg**. It is a very hard judgment for me to make. As a matter of fact, I think we need more research on research. It is curious about that. That has not been a sort of high-status field in the sciences.

You know, the same people who demand rigorous evidence in laboratory experiments will make ex-cathedra pronouncements about the nature of the scientific process and discovery and application and so on, and I have found it very frustrating, actually, to get a strengthening of research on research. At least I don't feel qualified to answer your question very well.

I do want to caution a little bit, though. I think that, on the development end, that is clearly, in large part, an industrial function. The basic research is, in large part, a university function, and mainly federally supported.

In between, there is a spectrum of applied research that kind of relates to the basic. I think Government support of that is very worthwhile. But exactly where you draw a line, I couldn't draw it precisely. Maybe Dr. Fechter might want to comment.

Dr. **Fechter**. I wouldn't take that one on with a 10-foot pole. But I will comment on what Federal policy might do to kind of stimulate the very productive industry-government relationship that Dr. Hamburg referred to.

There are some experiments going on now which we could look to with some interest. I think one is, of course, the NSF experience with the Young Investigator Program, where there is an attempt to supply matching funds. The Federal funds are contingent on matching funds from wherever. Industry could be one source of "wherever."

The other experiment which I look on with great interest is—I think it is being done by the States. A number of States are putting up money for endowing certain kinds of professoriates, again with a matching component to the State universities. If the State universities can come up with matching funds, then they will get some State funds to support a distinguished chair for professor XYZ.

The idea of matching is a very useful one. It gives incentives, I think the appropriate incentives, and I think it is a very efficient way of directing Federal dollars.

Dr. HAMBURG. May I bring Dr. Wells in on this one?

Dr. WELLS. Well, actually, I wanted to add one thing to Mr. Mineta's question about the surplus with respect to physicians except in the engineer area. It has to do with not just engineers but really looking to the future at long-term projections of demand for manpower and what kinds of assumptions you make. Case in point: for example, the Japanese, with a population half of that of the United States, graduate more engineers each year and use them. It is conceivable that over time concepts of staffing organizations, manpower concepts, in this country will change over time as organizations become more technologically based.

As science and technology, as new industries arise, we may ourselves look to the Japanese experience and see what we can learn or at least what things we might want to consider adapting, and therefore these kinds of intangibles can have enormous influences on your whole manpower projections if you just simply change the notion that engineers just don't belong in the design department but they should be all over the organization, a la the Japanese model. So that is another little fly in the ointment as far as future projections.

Mr. MINETA. Thank you very much. Thank you, Mr. Chairman.

Let me make just one quick point, and that is to follow up on what Dr. Wells said. It seems to me that maybe 5 years ago, 10 years ago, in order to become the president of the company, the chief executive officer, you had to be from the operating side, the engineer, the scientist. Today it seems to me that now the chief executive officer is the chief financial officer or the general counsel, and so now I think we may even see a shift in that part of it as well.

Thank you very much, Mr. Chairman.

Mr. WALGREN [resuming as Chair]. Thank you, Mr. Mineta.

Well, let me, on behalf of the task force, thank you all for your contribution to the record and being a resource to this process. We appreciate it very much.

Dr. HAMBURG. Thank you.

PANEL 2

Mr. WALGREN. Let me call the second panel. Obviously, in the interest of time, we have to keep that in mind, and knowing that people have other commitments as 12 o'clock comes, if the witnesses can put that in the backs of their minds, we certainly would appreciate it.

In that sense, I would like to encourage you to summarize and outline your testimony, underscoring those points that you feel really deserve to be highlighted in the record, and that will leave more time for some flexible discussion.

The second panel is made up of—and I want to make sure we have it in the right order—Prof. Dan Kleppner, who is a physicist with MIT; Mr. Don Brown, who is a petroleum consultant with Brown & Associates; Mr. Billy Reed, who is a practicing engineer with the American Engineering Association, and Dr. Ronald Rahn, who is a microbiologist with the National Institutes of Health.

So welcome to the task force, gentlemen. Why don't we proceed in the order in which I have introduced you? Again, please feel free to outline and summarize your statements and the points that you feel most important to make in whatever way you feel most effective in doing that. As I say, written statements will be made part of the record, so we can converse in a more informal way in this process. So please proceed.

Oh, one other thought. We apparently need to use both microphones because the small microphone is tied into a recording system that then will result in transcription of the verbal testimony. So, as we go through, if you will just pass both microphones down the line, it will work out fine.

Professor Kleppner.

[A biographical sketch of Dr. Kleppner follows:]

Dr. Daniel Kleppner

Daniel Kleppner is the Lester Wolfe Professor of Physics at the Massachusetts Institute of Technology where he has been on the faculty since 1966. He was educated at Williams College and Cambridge University and received his Ph.D from Harvard University in 1959. His research is in atomic physics, and his interests include high precision measurements and fundamental constants, highly excited atoms and spin-polarized hydrogen. He is a co-inventor of the hydrogen maser atomic clock and the co-author of two textbooks. Professor Kleppner is a Fellow of the American Physical Society and the American Association for the Advancement of Science, a former Chairperson of the Division of Electron and Atomic Physics of the American Physical Society, a member of the National Research Council Committee on Atomic and Molecular Science, and a member of Physics Survey Committee.

STATEMENT OF DR. DANIEL KLEPPNER, LESTER WOLFE PROFESSOR OF PHYSICS, MASSACHUSETTS INSTITUTE OF TECHNOLOGY, CAMBRIDGE, MA

Dr. Kleppner Mr. Chairman, thank you for the opportunity to discuss questions of manpower and supply. I am going to discuss the question specifically with respect to physics.

We have a valuable resource in the Manpower and Statistics Division of the American Institute of Physics. That division has recently completed a study on manpower and supply in physics for the forthcoming physics survey, and that has been appended to the document that I submitted. The bottom line of this is that we project a precarious balance between demand and supply through the early 1990's. Beyond that, there are likely to be more opportunities than new physicists to fill them.

By way of background, I might say that the whole question is so complicated, and the difficulty of understanding statistics so formidable, that I went back to the original survey, the Bromley report, which was published in 1972, to look at the projections of this same group to see how they did between then and 1981. I was amazed at how accurate the projections were. This is no guarantee that the projections for the future are going to be accurate, but it does mean that this is a serious survey, a serious study, and that its conclusions should be regarded seriously.

Now, underlying this conclusion, there are a couple of qualitative changes which I would like to point out. One is the very rapid increase in the role of foreign students in the American graduate physics program. It has been noted that graduate students from abroad a decade ago constituted 20 percent of the first-year enrollment. That is now 40 percent, and the projections for the future indicate that it will continue to rise slightly. In the latter part of the 1990's, we are likely to have half or even more than half of our graduate students being foreign-born students.

Another remarkable change which is coming, which can be quite accurately projected, I believe, is given in the figure S2-6. It is an estimate of the median age of faculties. The median age of physics faculties has been rising very rapidly since the early 1970's. It has been rising perhaps more rapidly than in any other science. It is now about 48 and still going up, and then it is suddenly going to plummet. In the midnineties, due to a very rapid rate of retirement, the median age is going to drop at about twice the rate it is rising right now.

[The information follows:]

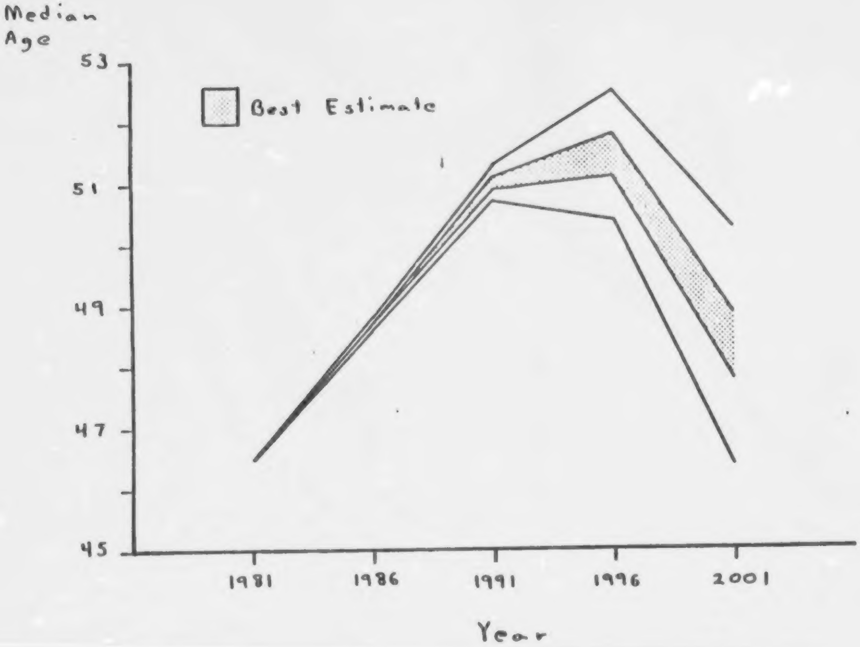

Figure S2-6. Projected Median Age of University Physics Professoriat at 5-Year Intervals, 1981-2001.

Dr. **Kleppner.** What this means is a major change in the hiring by physics faculties. There are going to be many new young people brought into these faculties. That is going to entirely change the employment situation at that time. This is a very dramatic change, and we have to face the question as to whether there will be an adequate supply of outstanding young physicists to meet that need.

I believe this is an overriding question, and I, myself, am very concerned that this line in the summary, "There are likely to be more opportunities than new physicists to fill them," rather understates the situation, because what we have here is the makings of a crisis.

I don't want to project a crisis. I don't believe that the manpower and statistics division would use that term. But it is foreseeable that one could occur. There are 300,000 first-year students taught in physics every year in this country. The majority go into engineering; the next largest group is for premedicine and biology. These students have to be taught. Universities will have to fill these positions.

If there are not enough highly qualified students available or young candidates available at that time for these positions, they are going to have to hire less qualified faculty members. This could signal a deterioration of universities. I don't think this needs to take place, but it could take place, and if that should occur, it would have very serious repercussions for the Nation, and I think it is very important that we prevent that from occurring.

I think I will conclude my comments with these points right now because I think these are the most overriding considerations that have arisen in consideration of the future manpower and supply.

[The prepared statement of Dr. Kleppner follows:]

Testimony by
Daniel Kleppner
Professor of Physics
Massachusetts Institute of Technology
to the
Task Force on Science Policy
Committee on Science and Technology
July 9, 1985

This Nation's accomplishments in physics have enriched our understanding of Nature and contributed to the welfare of people everywhere. In addition to pursuing basic research, physicists contribute to national programs such as energy and defense, and to a wide variety of industrial programs. Physics is a central science that contributes concepts, techniques and scientific manpower to the neighboring sciences, to engineering and to medicine. Currently, approximately thirty percent of the new Ph.D.'s in physics pursue careers in these other disciplines. Thus the health of the supply of Ph.D. physicists has ramifications not only for physics but for many other fields. For these reasons, the supply and demand of physicists in the future is of vital concern to the Nation.

A statistical and demographic study, The Education and Supply of Physicists (to be referred to as "the manpower study"), has been carried out by the American Institute of

Physics Manpower Statistics Division for the forthcoming Physics Survey. A draft is attached as a supplement. Although the manpower study has not yet gone through the review process, I believe that it provides a well informed discussion of the data and their interpretation. I would like to summarize its salient features and then to comment on them from my personal perspective.

MAJOR FEATURES

Ph.D. production

The annual Ph.D. production climbed from 600 in the year 1960 to a peak of 1545 in 1970. It plummeted during the 1970's and leveled at about 950 by 1980. The rate appears to be starting to climb slowly. Based on current graduate student enrollment the rate is predicted to climb to about 1100 in 1988. Projections for the year 2000 range between 1000 and 1100 Ph.D.'s per year. A striking demographic feature is the increasing rate of foreign-born graduate students. In 1970 less than 20% of the first year graduate students were foreign born: by 1983 the fraction increased to 40%. The projections for the turn of the century suggest that about half of our Ph.D. production will consist of foreign-born students.

Academic Employment

There have been tumultuous changes in academic employment as the rapid expansion in the 1960's abruptly terminated at the end of the decade. As a result, a middle age "bulge" has developed that dominates the future academic openings. The retirement rate will soon start to climb. The tenured academic openings in universities will increase steadily from a number of 750 during the five year interval 1981-1986 to nearly 1200 in 1996-2001.

Demand Scenarios in Industrial and Other Non-Academic Sectors

The majority of the employment opportunities for Ph.D. physicists in the next decade will be in industry, Government laboratories and non profit organizations. Sixty percent of the currently employed Ph.D. physics work in these organizations: approximately half of them work directly in physics. The manpower study has projected the employment demand for a variety of conditions ranging from conservative economic growth (2% per year) with low outmobility of physicists to other fields (1% per year), to moderate growth (3% per year) and moderate outmobility (1.45% per year - the current rate). The total number of positions in the period 1981-86 is projected to range from 1560 to 2100, and in the period 1996-2000 from 2120 to 2740.

Summary - the Demand-Supply Balance.

The manpower study concludes that there should be an approximate balance between demand and supply for Ph.D.

physicists through 1991, but that later in the decade the supply of new physicists may not match the new openings (see Fig. S2-9, p. S2-37). However, the study suggests that the divergence between supply and demand may be greater than indicated because it does not include projected increases in neighboring scientific and engineering areas where physicists have always made important contributions. Thus, the projected balance between demand and supply through the early 1990's is described as "precarious".

COMMENTS

I would like first to respond to the Chairman's inquiry as to how my own field - Atomic, Molecular and Optical Physics - is faring in the current job market and what future trends are anticipated. The demand for Ph.D. physics in this area is high, largely because of the impact of lasers and the growth of modern optics. There are jobs available in all three principal sectors - academic, government laboratories and university laboratories. In viewing these employment needs, however, it is important to reorganize that physicists are a flexible breed, and that many physicists will readily move into new research area if the intellectual challenges and/or employment opportunities are compelling. To cite two personal examples: One of my students whose Ph.D. research was in low temperature physics took an industrial position to develop laser gyroscopes. He has been very successful, notwithstanding that he had absolutely no previous experience with lasers. Another student whose research was on atomic structure accepted a position developing new techniques for physiological analysis and medical testing. He is also doing very well. These are by no means isolated instances: training in physics provides students with the ability to pursue any number of careers, and physics has traditionally served as a feeder for the other sciences.

A healthy community of physicists is an essential resource for the Nation irrespective of the particular areas in which the physicists have been trained. This was demonstrated in World War II by the ease with which physicists with diverse backgrounds moved into new research areas to carry forward the Manhattan Project and the development of radar at the M.I.T. Radiation Laboratory. The influx of foreign physicists in the 1930's provided a major component of that physics community. After World War II the United States assumed pre-eminence in physics and we no longer had to rely on foreign-born talent. As the data in the attached manpower study indicate, however, the number of U.S. graduate students has dropped and we are increasingly relying on foreign-born students to meet our manpower needs. In the past, approximately half of these foreign-born students remained in the U.S. However, the research environment in the U.S. continues to be strained while the environment in many foreign countries may be improving. We are in a highly vulnerable situation because any change in the foreign student retention rate would have large leverage on our scientific manpower supply. Furthermore, foreign-born physicists are often ineligible to work on military-related research. The decreased size of the U.S. enrollment in our graduate programs is, I believe, an ominous situation.

I believe that the overall balance between supply and demand in physics is a more critical concern than the particular areas in which students carry out their Ph.D. research. For example, the current production of Ph.D. optical physicists per year is only fifty - not nearly enough to satisfy the Nation's current and projected industrial, government and academic needs. However, for the present we do not have an employment crisis in this area due to the outflow of physicists from other areas, as in the case cited above.

Behind the statistic of the education and manpower study one can sense qualitative changes that will affect the future education of Ph.D. physicists in the U.S. For instance, many universities are finding it increasingly difficult to find fully qualified candidates for their junior faculty positions. In experimental condensed matter physics these universities report a severe shortage. Condensed matter physics is a unique field in that it possesses major industrial resources for basic research. In former times the most promising young scientists would choose careers from among industrial laboratories such as Bell or IBM and the universities. This is no longer the case. Even the leading universities report that they can no longer compete with industry for the best talent.

The shortage of outstanding faculty candidates in condensed matter physics is not simply a result of the industrial competition: that has always existed. It is because today many young scientists feel that they cannot look to the universities to provide the environment required for forefront research. They see that the university laboratories are poorly equipped, that their professors must struggle to carry forward research without adequate support and spend their time hunting for money rather than devoting themselves to research and teaching. They see a situation in which the university groups are losing their ability to compete in research with industrial laboratories and laboratories abroad.

Today it is not unusual for some of our leading universities to search for several years in order to fill a junior appointment. If the universities are already starting to experience shortages of outstanding faculty candidates, then the probability is high that in the 1990's when new faculty positions proliferate due to the rapid increase in retirements, there will be a severe shortage of qualified candidates.

There is wide concern throughout the academic community in the United States about sustaining the quality of education and scholarship. My own university - the Massachusetts Institute of Technology - has recently formulated a long range plan that addresses these issues. The Institute intends to improve the atmosphere for academic research by trying to generate more internal support, particularly support for young faculty members, and to increase faculty salaries. However, the level and nature of federal support is an overriding problem. To quote from MIT's long range plan

> Since World War II, as the research universities grew, research and scholarship advanced and grew more complex, requiring a level of funding which in large part could only be provided by the federal government. As the level of support has grown, many of the federal offices that fund university research have retreated from the original, unwritten compact: that the government would support university research to make possible the education of successive generations of students and the preservation and growth of American scholarship, science, and basic technology.

The United States cannot maintain the level of physics that is essential for its national needs unless this unwritten contract is restored. I fervently hope that the Task Force on Science Policy is successful in this enterprise.

SUPPLEMENT
EDUCATION AND SUPPLY OF PHYSICISTS

The many opportunities for achieving major advances in physics research during the coming decades are discussed elsewhere in this overview report. While international cooperation and competition will continue to simulate the scientific enterprise, the maintenance of a U.S. leadership role in physics is important both for the vitality of physics as a field and for the technological position of the country as a whole. Asserting such leadership and meeting the scientific challenges and opportunities of the future clearly call for a strong base of highly trained individuals. This supplement describes the changing patterns in the supply and employment of physicists and poses questions concerning the availability of these manpower resources in the future.

The events of the past two decades have left us with an aging academic community, a smaller core of physicists regularly engaged in basic research, and a continuing high outflow of physics Ph.D.s to related areas of science and engineering. While graduate enrollments in physics began to increase in the 1980's, most of the increase reflected the rapid growth of the foreign student component. The continued decline in the number of U.S. physics graduate students, coupled with a low retention of Ph.D.s in physics, leads us to expect only minor increases in the physics labor force in the near future.

By the middle to late 1990's, greater than usual retirements, based on the large number of entries in the 1960's, are expected. It is possible that the supply of entrants into the physics labor force could decline at the very time when retirements will be most numerous. Although alarmist cries of shortage and pleas for a return to the high production levels of graduates during the late 1960's would be inappropriate, concern over the effects of a potentially diminishing labor force is warranted.

In the following sections, we describe the major aspects of the current situation and the issues they highlight, including an analysis of the contributory events of the past two decades. We conclude the supplement by projecting physics manpower in the coming decades. Because the production of highly skilled physicists is a long-term process calling for extensive lead time, developing such projections takes on added import.

S2.1 Producing Trained Young Physicists - A Historical Overview

Initial decisions affecting (or precluding) later careers in science are typically made in the early teen years. Students who do not enter the advanced science and mathematics sequence at the secondary-school level are unlikely to be prepared for college-level science courses. They are even less likely to consider majoring in physics. In the United States, however, less than half of secondary school students take more than 2 years of science and mathematics. A much smaller proportion (less than 20% of 1980 graduating seniors) is exposed to physics. The value of even that limited exposure is being questioned in light of the shortage of qualified mathematics and science teachers. Many of the competent teachers have left for more prestigious and remunerative job opportunities, while the number of new science teachers being trained has declined severely.

This deteriorating condition of precollege science and mathematics education has long been of concern to the physics community. By the 1980's it had become a national concern.* The crisis in secondary-school education raises serious questions about the future scientific literacy of the Nation and the development of the needed pool of potential scientists.

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*See, for example, A Nation at Rest, A National Commission on Excellence in Education, 1983, and Teacher Shortage in Science and Mathematics, NIEE, 1983.

The training of a professional physicist is both lengthy and selective. Only a small proportion of the individuals exposed to physics at the college level actually major in physics. A still smaller number enter physics graduate study and emerge from 4 to 9 years later with a Ph.D. This core of individuals constitutes a unique group with a high level of intellectual ability and an array of flexible, sophisticated skills. They are a precious national resource. It is this group that will be responsible for the continuing physics research effort; for the training of the next generation of students, researchers, and teachers; and for providing the talent that offers important stimulation to a wide variety of related scientific and engineering disciplines.

Following a rekindled interest in the physical sciences brought on by Sputnik and increased Federal support, the total number of physics graduate students climbed rapidly during the 1960's, rising to over 15,000 in each of the last 3 years of the decade. In 1969-70, Ph.D. production peaked at 1545 (Figure S2-1), a 148% increase since the beginning of the decade.*

Employment opportunities in academe were bright during the early 1960's because of the marked upsurge in the number of students and increased Federal grant money for research. New physics Ph.D.s quickly filled the assistant professor ranks. There were a large and ever-increasing number of positions in research and teaching. Although it was difficult to believe at the time, such high rates of expansion could hardly be expected to continue indefinitely.† They did not. Towards the end of the decade when the physics student body was approaching its peak, harbingers of difficulties ahead began to appear. Federal funding for basic research slowed with the Nation's heightened

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*Data are derived from AIP's annual departmental surveys of enrollments and degrees. Figures may differ slightly from those obtained from othe sources, e.g., NAS and NSF. Nearly 100% of physics departments have traditionally responded to these annual AIP surveys. Data from missing departments are estimated on the basis of the previous year's responses.

†Physics: Survey and Outlook, NAS, 1966.

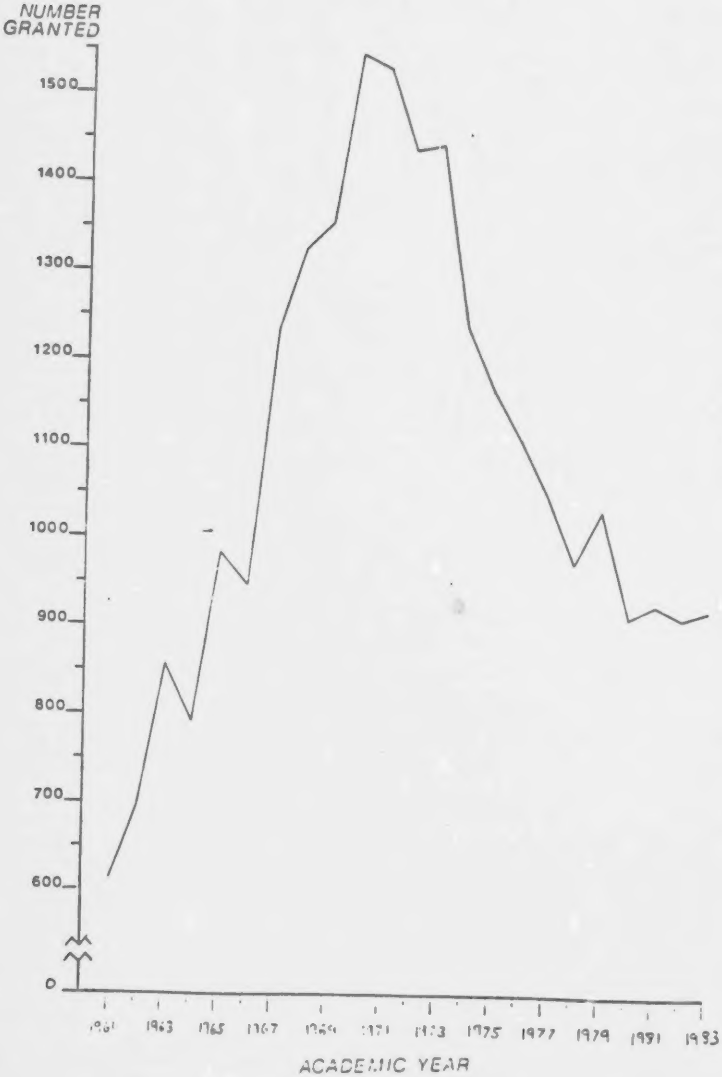

Figure S2-1. Physics Doctoral Degrees Granted, 1961-1983.

involvement in the Vietnam War.* The Mansfield Amendment had the effect of curbing basic research support from many of the traditional mission agencies, and the National Science Foundation was unable to assume fully the burden of support. New academic positions diminished in number, and the economy (which had not been particularly robust), presented only limited alternative job opportunities.

When the large new classes of physics Ph.D.s entered the employment marketplace at the beginning of the 1970's, traditional opportunities had nearly vanished. Many more Ph.D.s than usual took temporary postdoctoral positions, hoping to wait out the economic doldrums. Despite the unfavorable job market, most new physics Ph.D.s did find science-related positions, although not always long-term ones in physics research. The dashing of expectations for traditional university research careers in the first half of the 1970's brought bitterness to some and a changed perspective to many others.† Horizons were altered; more attention was paid to the varied work activities one could perform with a physics Ph.D. As the decade progressed, industrial employment grew, both in physics and in related science and engineering areas. Physics Ph.D.s adjusted their expectations and took advantage of the changing opportunities.

While new employment avenues began slowly to expand, degree production in physics plummeted. Bachelor's degrees had already begun to decline by the late 1960's; Ph.D.s soon followed, dropping from over 1500 at the beginning of the 1970's to little more than 900 by the end of the decade. This reaction to the difficult market conditions of the early 1970's eased the employment situation for the new Ph.D.s emerging in the middle to late 1970's. Job offers increased, and by 1980, only 2% of the Ph.D.s did not have job offers at the time their degrees were granted, compared to 25% at the start of the decade.

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*See Chapter 3 on research funding for further details.

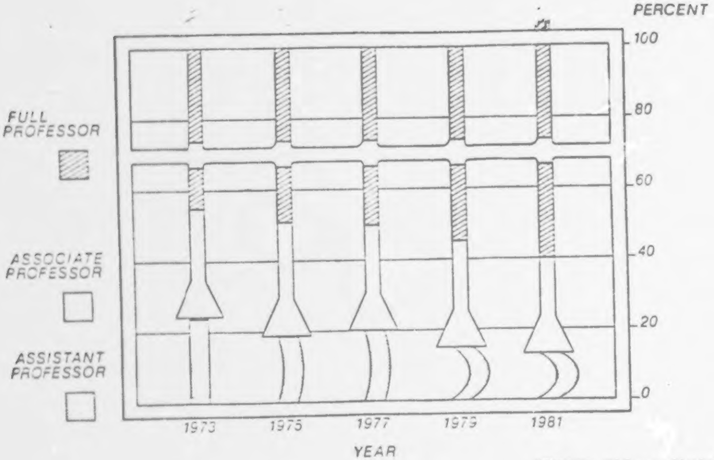
†The Transition in Physics Doctoral Employment, 1960-1990, APS, 1979.

This steep decline in physics degree production was occurring at the same time that the overall number of students in postsecondary-school education was rapidly growing. The products of the extended demographic "baby boom" of the 1950's, encouraged by the availability of educational loans, filled the colleges in the 1970's. Many students entered the biological and social sciences, but few of them majored in physics. Ph.D.s in physics, in fact, represented only 7% of all natural science and engineering doctorates in the late 1970's, down from the 11% figure which had been relatively constant for several decades. Although such a shift might have augured well for the competitive employment position of new physics-degree holders, it raised concern about the availability of future human resources in physics.

Academe was the one area where employment opportunities for new physics Ph.D.s had not altered by the beginning of the 1980's. The large number of young physicists who had swelled the ranks of the assistant professors in the 1960's were now tenured but still far from retirement. In 1980, assistant professors represented only 14% of academic physics staffs, a lower percentage than in any other scientific discipline (Figure S2-2). With few senior positions opening, even some of these assistant professors would not receive tenure. The effects of this "missing generation" of young academics are reflected in the marked aging of university physics department staffs from a median age of 38 in 1973 to 44 in 1981. This brief history of the past two decades of physics Ph.D. production and the labor market provides a background for discussing the important human-resource issues facing physics in the 1980's.

S2.2 Enrollments and Degrees: The Prolonged Decline

As noted, physics Ph.D. production declined rapidly throughout the 1970's, dropping to the low 900s by 1980, and hovering at that level since. In 1980 the first-year physics graduate student enrollment was 2439, down 44% from the middle 1960's. Graduate physics enrollments had finally bottomed out; 1981 saw the first rise in enrollments in 15



SOURCE NAS unpublished data on Physics PhD's

Figure S2-2. Academic Rank of Physicists Employed in Universities and Colleges, 1973-1981.

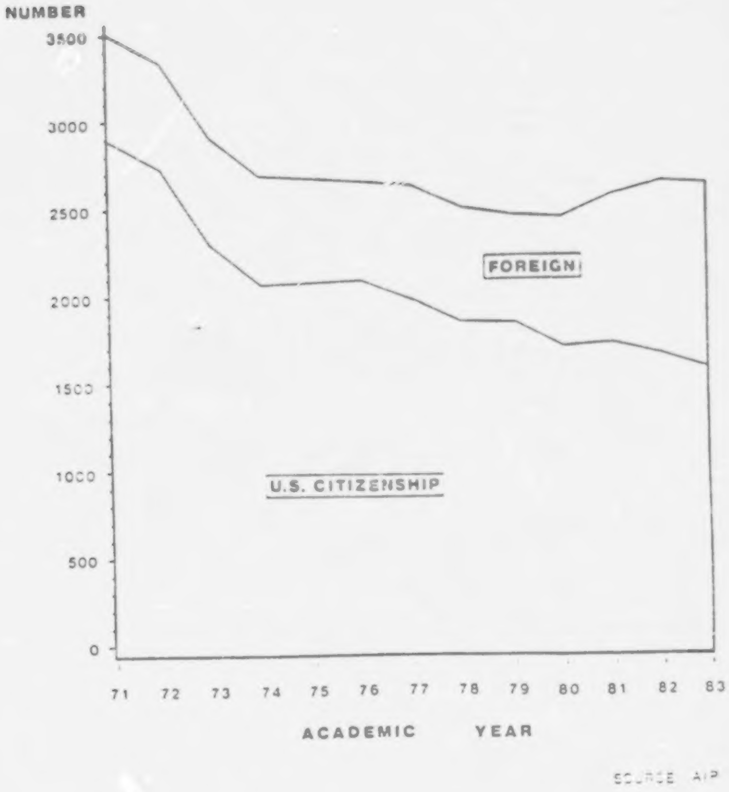
years. While it would be another 5 to 6 years before these increases could be reflected in Ph.D. production, an eventual turnaround seemed on the horizon.

S2.2.1 U.S. and Foreign Composition

Detailed analysis of enrollments, however, pointed up a new phenomenon. In the 1970's foreign students had formed about one-fifth of physics graduate students, or about 600 new foreign nationals a year. As the total number of first-year physics graduate students reached its nadir in 1980 and then began to increase, a major change in the citizenship composition of these students was also occurring. By 1983, over 1000 of the first-year physics graduate students were foreign citizens--40% of that entering class. U.S. university physics departments were drawing students from many countries, providing particular opportunities for students from the less-developed countries in Asia and the Middle East. This influx of foreign students, however, clouded another trend. The decline in first-year graduate enrollment of U.S. citizens in physics did not, in fact, bottom out in 1980; it continued through 1983 (Figure S2-3).

If there had previously been concern about the availability of highly trained physics manpower in the U.S., these data only accentuated the concern. What lay behind this continued decline in U.S. graduate students? Although most academic opportunities remained tight, the general employment situation for new physics Ph.D.s was healthy. Job offers were strong, and starting salaries were high. Were the front-paged breakthroughs in the biosciences, the new technology excitement of computer science, and the financial rewards of the professions drawing bright potential physics students away? Such changes in student career directions could have a major impact on a comparatively small area of concentration like physics.

In 1984, first-year foreign graduate students continued to increase; however, U.S. enrollments for the first time in many years increased even more. Although 1985 saw a flattening of these trends, the current hope



SOURCE: AIP

Figure S2-3. First-Year Graduate Physics Students by Citizenship, 1971-1983.

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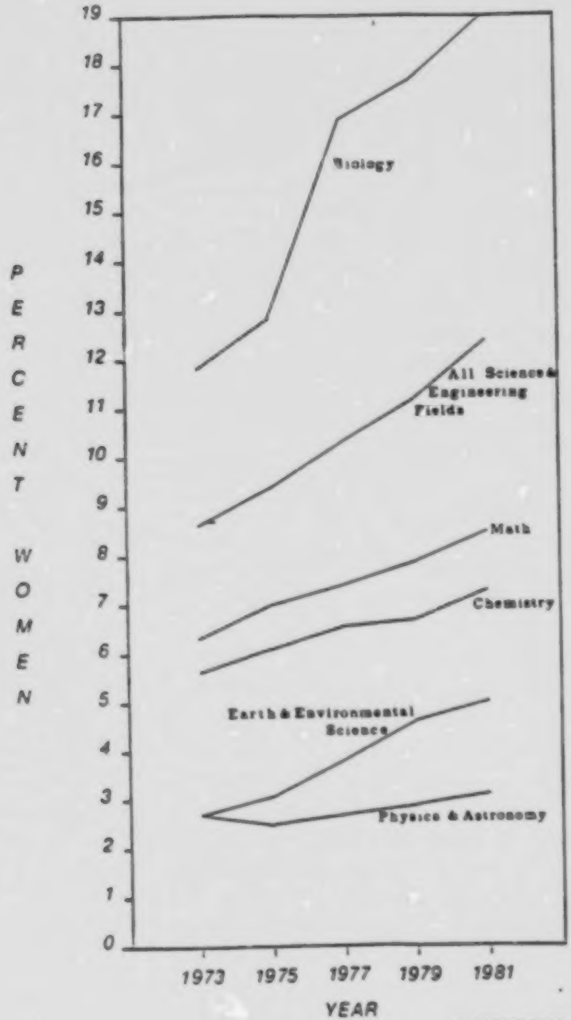
in what had been a long time in U.S. first-year enrollment provided at least a temporary sense of relief to the physics community. (Sic.)

S2.2.2 Women and Minorities

Despite intensified efforts on the part of professional societies in physics and of related women's groups, women still represent only a small proportion of Ph.D. physicists (Figure S2-4), approximately 3%, the lowest among the major scientific areas. New physics Ph.D.s include a higher proportion of women, but the actual number of doctorates awarded to women has not changed since the middle 1970's--approximately 65 per year. In most science and engineering areas, increased degree production has reflected the growing participation of women. Enrollment of women in the formerly male bastions of engineering and computer science, particularly at the undergraduate level, has skyrocketed. The same cannot be said of physics.

The reasons for the continuing underrepresentation of women in physics are not yet fully understood. Women constitute the major untapped future resource for the physical sciences and engineering; nowhere is that more true than in physics. Whether one is thinking of the future development of the field, or of equal access by all segments of the population, the minimal participation of women in physics remains a major concern.

If the representation of women in physics is low, the representation of indigenous U.S. minorities, i.e., Blacks, Puerto Ricans, Mexican Americans, and Native American Indians, is even lower. They make up less than 1% of the physics labor force; total production at all degree levels remains low. Full representation is found only among Oriental Americans. This is a problem shared throughout the science and engineering community. Some inroads have been made at the bachelor's level in fields such as engineering and chemistry, and probably in computer science. Physics, with few direct entry-level positions, has seen no increase in the representation of indigenous minorities. If anything, the number may be decreasing.



SOURCE: NAS

Figure S2-4. Women as a Proportion of All Doctoral Scientists by Selected Fields, 1973-1981.

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S2.2.3 Declining Enrollments In Physics Subfields

The steep decline in physics Ph.D. production affected most of the major subfields of physics during the 1970s (Table S2-1). Degrees in Solid State Physics, Elementary Particle Physics, Nuclear Physics, and Atomic, Molecular, and Optical Physics dropped to less than half of their peak early-1970s levels by the beginning of the following decade; they have remained relatively stable since. Any continued erosion in subfield degree production may present threats to the research vitality of an area and could be a cause for concern in the entire physics community.

While degrees in Plasma Physics and Astrophysics also declined from their peaks in the early 1970's, the drops were not as precipitous. Only in Optics, one of the most applied of the major physics subfields, could a countertrend be observed; here, Ph.D. production doubled between 1971 and 1981. A similar increase was occurring in Medical Physics, although this area was not yet being monitored by the National Research Council.

S2.3 Retention of Physics Degree Holders - Mobility

Whether or not one thinks of physics as the "Queen of the Sciences," it is clear that physics has traditionally trained practitioners for other disciplines: at the bachelor's level for engineering, at the master's level for education and business, and at the Ph.D. level for a multitude of developing science and engineering areas. More than any other scientific discipline, physics has sent its Ph.D.s to related disciplines in order to serve society's growing technological needs.

Much of the outmobility of physics Ph.D.s has been into engineering and interdisciplinary areas such as geophysics, materials research, and biophysics, but Ph.D. physicists also work in a broad span of other areas ranging from chemistry to the biosciences. Some of this mobility occurred within academe where physicists teach and conduct basic research in related science and engineering departments. Most of it, however,

Table S2-1

Number of Physics Doctorates by Subfield, 1969-82

Subfield	Academic Year													
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Solid State	360	402	442	393	400	351	319	282	257	243	243	202	250	235
Elementary Particle	220	258	278	198	222	148	124	128	138	135	119	117	117	118
Nuclear Structure	188	212	227	234	182	144	130	96	93	77	103	73	62	53
Atomic & Molecular	127	152	124	150	122	120	138	116	105	88	72	69	65	96
Plasmas	61	85	86	93	74	57	53	75	72	68	62	59	65	69
Astrophysics	55	63	54	66	67	77	71	72	57	74	57	69	59	50
Optics	16	30	25	31	33	26	33	50	31	33	46	43	54	42
Acoustics	11	22	20	20	15	11	12	9	12	14	13	23	13	11
Other	369	385	425	387	411	344	353	329	321	270	335	278	280	287
TOTAL	1407	1609	1681	1572	1526	1278	1233	1157	1086	1002	1050	933	965	961

Source: NAS

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occurred in the industrial sphere where applications of physics research easily moved across disciplinary barriers.

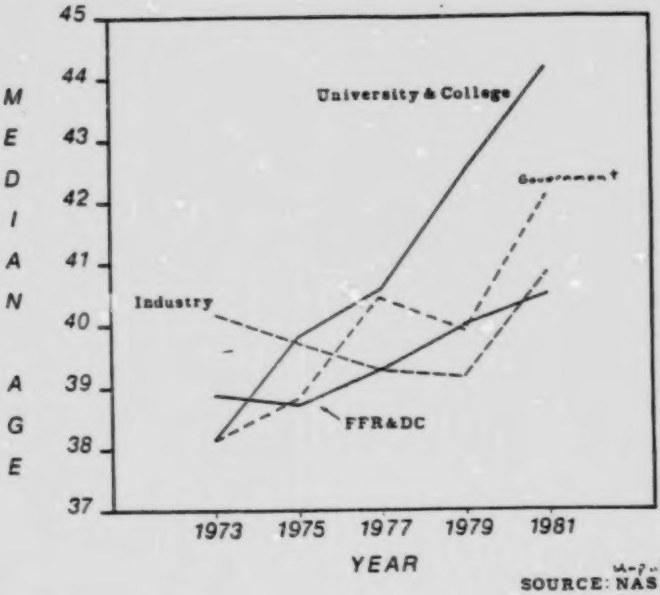
While patterns of high outmobility have been typical of physics and actually alleviated potential problems during periods of surplus, one must examine their impact during periods of dwindling supply. In the early 1970's, 30% of Ph.D. physicists were working outside of physics. As the economic support for physics research declined and alternative opportunities arose, the proportion increased to approximately 40%. Since the middle 1970's, employment opportunities in physics have improved; however, physics continues to provide needed skilled resources to other science and engineering areas at the same high rate. As the 1980's began, a large number of Ph.D. physicists were moving into the growing areas of systems and electronic engineering and computer science. In 1981, 27,000 physics Ph.D.s were employed in the United States; 10,400 of them were working in nonphysics areas.

Physics will certainly continue to provide many of its well-trained researchers to the new, growing areas of the future. Concern, however, may arise when this high level of outmobility is coupled with a decline in the supply of new physics degree recipients--the dominant pattern of the past decade.

S2.4 An Aging Community

The declining physics Ph.D. production during the 1970's, coupled with the departure of many young Ph.D.s to neighboring science and engineering areas, has produced a slow aging of the physics community over the past decade. This aging was most marked in academe where opportunities for young physics faculty remained blocked by the highly tenured-in staff at most physics departments and the lack of funds for staff expansion (Figure S2-5).

In the early 1970's, physics faculties, at a median age of 38, may have been preternaturally young, reflecting the heavy influx of new



SOURCE: NAS
unpublished
Data

Figure S2-5. Changing Median Age of Physicists by Employment Sector. 1973-1981.

Ph.D.s during the previous decade. This was certainly not true in 1981, by which time the academic physics community had aged by an average of 6 years to 44. They were not only the oldest group within the physics community, but they were also older than academics in other science disciplines (Table S2-2). Most of the full professors who by 1981 made up the majority of the academic physics staff were still, however, more than a decade away from retirement. Thus, additional aging is expected in academe through the 1980's, although some expansion of opportunities appears likely as retirements slowly begin to increase.

The universities provide the major stimulus for the important basic research that drives the development of the entire field. An aging faculty raises a number of issues. The most obvious one is the lack of academic opportunities for young physics Ph.D.s.* At the predoctoral, postdoctoral, and junior faculty levels, young physicists have traditionally made major creative contributions to forefront basic research in physics.† The full effect of these contributions frequently does not appear for several decades; thus, many of the accolades of the 1980's have their source in the research activities of young physicists in the halcyon decade of the late fifties and early sixties. The relative absence of young researchers from today's academic scene is a cause for concern about our ability to pursue effectively the opportunities that lie ahead in physics.

The increasing predominance of the older physics faculty member brings an additional concern to the fore. Physics has traditionally attracted a very small number of women and indigenous U.S. minorities. Cultural attitudes towards women and minorities in the sciences and other areas dominated by white males have been shifting; however, a paucity of role models exists. To what extent these attitudes are reflected in the

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*Physics Careers, Employment and Education, AIP Conference Proceedings Number 39, 1978.

†See, for example, Jonathan R. Cole, Stephen Cole, Social Stratification in Science, University of Chicago Press, pp. 107-109, Chicago, 1973, and Robert K. Merton, The Sociology of Science, University of Chicago Press, Chicago, 1973.

Table S2-2

Age Distribution of Full-Time Employed Ph.D. Faculty Members by Selected Departments, Spring 1980.

FIELD	AGE (Percent) Under 30	30-39	40-49	Over 50
All Fields	5	33	32	30
Physical Sciences	3	28	36	33
Chemistry	4	30	34	31
Geology	5	29	34	31
Physics	2	25	38	35
Engineering	6	28	36	29
Chemical	9	26	32	32
Civil	4	31	38	27
Electrical	6	28	36	30
Mechanical	6	26	38	30
Mathematics and Computer Science	8	38	30	22
Mathematics	8	37	31	24
Computer Science	12	43	26	18
Biological Science	3	35	29	33
Biology	3	35	30	31

Source: National Science Foundation

aging academic physics community is unclear. The importance for the future of actively reaching out to these potential physicists from nontraditional backgrounds, however, is clear; accomplishing such communication may require skills that many of the older physics faculty have not yet developed.

Physicists have also aged in other economic spheres. Except for the in-house Government laboratories where funding cutbacks had been particularly large, however, such aging was minimal in contrast to that observed in the universities. In fact, the median age of the population of physicists employed in industry decreased during the 1970's as young physicists sought out new avenues of employment both within and outside physics.

S2.5 Changing Patterns of Employment

Patterns of physics employment underwent major changes in the past decade. In the early 1970's, half of all physics Ph.D.s were academically employed. By 1981, the proportion had dropped to about 40%. Academic growth in physics during the decade was sluggish, with teaching staffs actually declining in size through 1979.

Employment of physics Ph.D.s in industry, on the other hand, burgeoned from under 5000 Ph.D.s in 1973 to over 8500 in 1981, representing in the latter year nearly one-third of all employed physics Ph.D.s. The steady growth in industrial employment of physicists reflected the favorable climate in that sector as well as the closing of academic doors. Although some of these new industrial opportunities were in physics itself, the areas of highest growth were in related sciences and engineering. The physicists who pursued these openings were, in general, primarily involved in development and design, and secondarily in applied research. Basic research has generally played a minor role in industrial employment. The proportion of industrially employed Ph.D.s engaged in basic research continued to decline over the period, falling to below 10% by the end of the 1970's.

Employment in the national laboratories, which had remained virtually unchanged during the otherwise expanding 1960's, increased steadily through the 1970's.* These laboratories offered special opportunities, in addition to providing a home for some of the basic physics research which had traditionally been carried out in the universities. However, the major increases occurred in the areas of applied research, as the national laboratories took on more diversified missions. In fact, by the beginning of the 1980's, a shift in emphasis at these laboratories from basic to applied research had occurred. Employment at in-house Government laboratories showed only minimal growth throughout the decade.

These changing patterns of employment, particularly in the industrial sphere, allowed for the absorption into the economy of the unusually large number of new physics Ph.D.s who emerged into the marketplace during the early 1970's. These Ph.D.s were not always doing what has been traditionally termed physics, but relatively few of them experienced any prolonged unemployment. In 1970, when Physics in Perspective was being developed, in the midst of a period of increasing hardship, the National Academy of Sciences report noted:

> The 1970's have begun with recognition of a critical employment situation and the realization that the traditional patterns of employment in physics are changing. If physicists understand the nature of this change, are flexible in their attitudes and will undertake careers not only in physics, but in related disciplines and specialties that also offer challenging problems, the outlook for the future could be more encouraging than was first assumed.†

Physics Ph.D.s appeared to have followed this dictum well. The entry of young physicists into the growing areas of applied research and technology provided an important dynamic for the development of a multitude of exciting new applications of physics research, from telecommunications through medicine.

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*National laboratories, such as Brookhaven and Fermi Laboratories, are completely funded by the Federal Government, but are administered by universities, industry, and nonprofit groups.

†Physics in Perspective, NAS, 1972, p. 856.

Basic physics research did not enjoy the same healthy expansion, although a core of dedicated researchers did manage to weather the vagaries of an uncertain decade and continued to carve out new avenues of exploration at the forefront of physics. If basic research is to remain vital through the rest of the 20th century, it is important to guard against any further erosion in this dwindled pool of human resources, and to encourage the infusion of new talent.

S2.6 Projections

Projections of demand and supply are crucial to any understanding of future balances in scientific manpower. These projections are an attempt to understand what appears most likely to occur to the physics labor force under different assumptions regarding expected changes in demand and supply. They should not be treated as predictions, but rather as probable outcomes under given scenarios. Table S2-3 summarizes the critical parameters of the demand and supply models.

S2.6.1 Demand Projections

The demand for physicists in the future involves both replacements for current positions and growth, both directly in physics and indirectly in related disciplines. Our concentration here will be on Ph.D. physicists working in physics. Because the expected demand scenarios in academe and outside it are quite different, they will be treated separately. Scenarios cover the period 1981-2001.* Estimated figures are presented for cumulative 5-year periods in order to minimize unpredictable year-by-year fluctuations.

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*The NAS biennial surveys have been used both to establish the employment patterns of physicists in the base year 1981 and to estimate mobility rates. 1981 is the last year for which data from the NAS biennial surveys are available.

Table S2-3

Parameters in Demand and Supply Scenarios

Parameters in Demand Scenarios

- Demand for physicists in universities and colleges
  - Openings, no growth
    - Death and retirement: age structure
    - Outmobility from academe
  - Patterns of replacement
    - Service course loads and demographics: future enrollments
    - Promotion rates
    - Age and tenure status of new hires
- Demand for physicists in industry, Government, and Federal laboratories
  - Openings due to replacement
    - Death and retirement
    - Outmobility from physics
  - Openings due to growth
    - Economic growth, R&D, and defense spending

Parameters in Supply Scenarios

- Physics Ph.D. Production
  - Demographic age factors and patterns of enrollment in higher education
  - Perception of technological opportunities and choice of major
  - Retention in the educational system
  - Entry of foreign graduate students
- Available supply of new physics Ph.D.s
  - Net migration of foreign nationals
  - Immediate outmobility to other fields

Academe. The academic employment of Ph.D. physicists has undergone tumultuous changes during the past two decades. Few labor force analysts writing during the expansionary period of the 1960's envisaged the tight academic market that would dominate the physics scene throughout the 1970's and into the 1980's.* These abrupt changes have produced a unique age structure: In 1981, 40% of university physics faculty were over 50 years old, while another 40% were between the ages of 40 and 49. This middle-aged "bulge" has a major effect upon any projections of future academic openings.

Death, retirement, outmobility, and promotion rates take on added importance when such large numbers of individuals are concentrated in the older age groups. We are assuming constant age-specific death rates for our academic professoriat, based upon current TIAA-CREF mortality schedules for males.† However, while the age-specific death rates remain constant, the numbers of probable deaths and potential openings will escalate as the middle-aged bulge of 1981 ages.

Retirement practices are not as clear-cut. The laws deferring mandatory retirement to age 70 were extended to academe in 1982. However, TIAA-CREF officials do not yet see any evidence of a further shift toward delayed retirement. If anything, they see some increased tendency for academics to seek early retirement. Thus our model allows for some early retirement and for half of the physics faculty members still working at age 65 to remain employed beyond that age. The combined effects of death and retirement should thus bring a dramatic increase in university employment opportunities in the 1990's.

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*Alan Cartter was less sanguine than many of his colleagues about the continuing expansionary needs of the future, but his voice was not the dominant one at the time.

†TIAA-CREF is the dominant retirement annuity fund for academics. Thus, their mortality schedules are most appropriate for use here. They will also be used when dealing with nonacademic physicists, since general mortality schedules would indicate death rates abnormally high for professional workers. In a community which is 95% male, the dependency on male death-rate schedules should not need need comment.

Academic positions can also be freed by mobility. However, few tenured older faculty have left academe in recent years, and, conversely, not many senior-level physicists have been drawn into academe from industry or Government. Movement into and out of academe by younger researchers, on the other hand, is an elastic and volatile phenomenon closely related to promotion rates and the availability of permanent senior positions. While AAUP rules set maximum time periods for which one can remain in untenured positions, they do not establish minimum times. If shortages develop, promotion policies are perhaps the most manipulable in the system. The model focuses on expected future openings in the senior ranks as the best indicator of long-term employment opportunities.

In addition to replacement needs, academic openings can result from growth. Total faculty demand is, we believe, more tied to service course loads than to basic research needs. By the mid-1990's, the 18- to 24-year-old age group, from which college students are traditionally drawn, will decline by over 20%. How many of them will attend college and take physics is, of course, the central issue. If tomorrow's students continue to need a strong technological background, then it is unlikely that enrollments in traditional science areas such as physics would suffer as precipitous a decline. However, it is questionable whether they would move so counter to the overall expected decline in student bodies as to produce a demand for faculty growth. Thus, the following scenarios assume that there will be no real growth in academic physics faculties through most of the remainder of the century.

Demand Scenarios - Universities. Our projections for university physics demand involve the following three major scenarios. In each scenario, replacement positions refer to existing senior positions vacated through death, retirement, and mobility out of academe.

- All replacement positions are filled.
- 10% of replacement positions become unavailable.
- 20% of replacement positions become unavailable.

All three scenarios recognize the expected decline in traditional university students in the late 1980's and 1990's and incorporate some countervailing swing towards increased demand for service courses in physics and other hard sciences. We feel the second scenario, which assumes a moderate shift toward a more science-oriented student body, is the most likely. It should be recognized that any cuts in physics faculty will hit some institutions harder than others.

Under the three replacement scenarios, the median age of the university physics professoriat, 46.5 in 1981, can be expected to continue to climb by an additional 4 to 6 years through the early 1990's, peaking at somewhat over 50. Thereafter, a rapid decline in median age is expected as staff from the middle-aged bulge of 1981 begin to retire and young academics fill out the professorial ranks.

Figure S2-6 illustrates the probable ranges in future median ages based on extrapolations from past hiring and promotion practices. By 2001, professors under 40 will increase to between one-quarter and one-third of the total physics staff, not as high a proportion as was found in the early 1970's, but a more substantial base than is currently observed.

Demand Scenarios - 4 Year Colleges. Physics faculties at the 4-year colleges are considerably smaller in number, and their age structure is notably younger, than are their counterparts in the universities. Possible openings due to death and retirement through 2001 are thus relatively limited. We expect the declining number of traditional college-age students enrolling by the 1990's to have a dramatic effect on the physics programs at the 4-year colleges, many of which are even now experiencing financial difficulties.

We present three possible scenarios, ranging from a severe staff reduction of 30% to a more modest one of 10%. Technological opportunities of the future and the relevance of a solid physics background may pull college students into physics courses at a higher

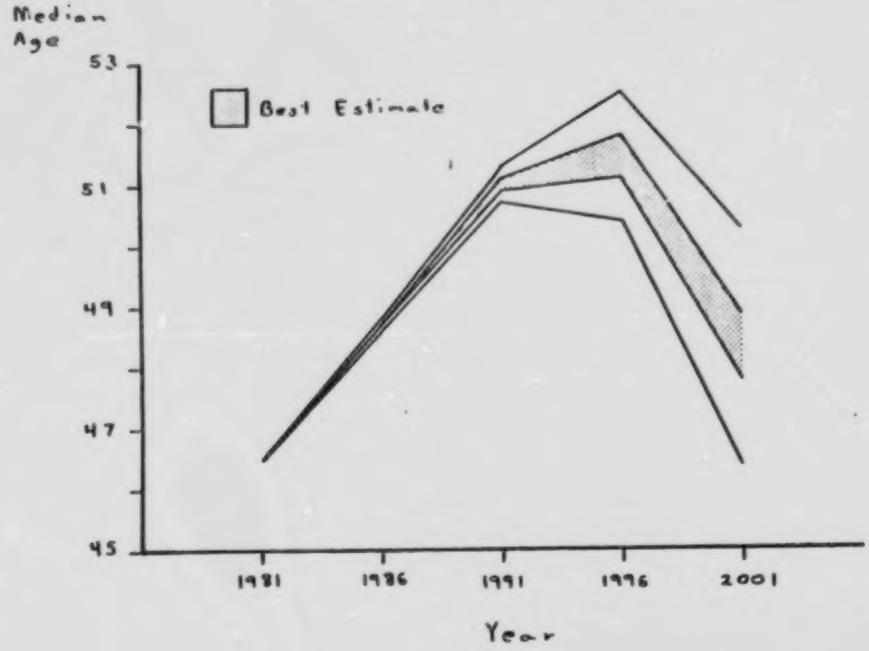

Figure S2-6. Projected Median Age of University Physics Professoriat at 5-Year Intervals, 1981-2001.

rate than currently observed. However, to achieve only minor staff reductions, physics departments at 4-year colleges will need to recruit more nontraditional students.

The accompanying tables for universities (Table S2-4) and 4-year colleges (Table S2-5) indicate the expected academic openings between 1981 and 2001 under the major scenarios outlined above. According to our intermediate scenario, tenured academic openings will increase steadily, swelling from 750 for the first 5-year interval (1981-1986), to nearly 1200 in 1996-2001. Whether new physicists will be available to fill these openings will be addressed later.

Demand Scenarios - Industrial and Other Nonacademic Sectors. Opportunities for physicists over the coming decade will derive primarily from openings in industry, Government laboratories, and nonprofit organizations, where 60% of Ph.D. physicists are currently employed. About half of these physics Ph.D.s are working directly in physics.

Since only 20% of these physicists were over the age of 50 in 1981, death and retirement will not be major sources of openings during the rest of the century. Most analysts, however project some growth, in contrast to the projections for academe. Highest growth is expected among small consulting firms and medical laboratories.* Growth is also expected in the larger electronics and communications industries where many physicists are concentrated. While Federal employment is not expected to be a major source of new positions, the national laboratories should continue to provide moderate growth in employment opportunities for physicists. We will use variations around the Bureau of Labor Statistics intermediate projections to describe expected growth in overall physics employment outside of academe.†

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*See, for example, Industry - Occupational Employment Matrix. Bureau of Labor Statistics data tape, 1980, and Problems of Small, High-Technology Firms, NSF 81-305.

†Occupational Projections and Training Data, BLS, Spring 1984.

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Table S2-4

Projected Number of Physics Openings in Universities, Resulting from Death and Retirement of Senior Staff, 1981-2001.[a]

	ACADEMIC YEARS				
	1981-1986	1986-1991	1991-1996	1996-2001	Total 1981-2001
Number of Openings Due to Death and Retirement	769	911	1018	1119	3815
Number of Openings Filled by Replacement Scenario[b]					
Low	615	729	814	895	3053
Intermediate	692	820	916	1007	3436
High	769	911	1018	1119	3815

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[a] Senior staff are defined as physics Ph.D.s employed as associate or full professors in universities. Figures for the base year 1981 were derived from unpublished NAS data.

[b] The high scenario assumes that university physics departments will attract undergraduate enrollment at significantly higher levels than at present and thus will experience no decrease in staff size. The remaining two scenarios assume that universities will attract undergraduates at higher rates than at present but not high enough to justify current professoriate levels. Thus, the low and intermediate scenarios reflect the hiring potential if 80 and 90% (respectively) of senior staff openings are filled.

Table S2-5

Projected Number of Physics Openings in 4-Year Colleges, Resulting from Death and Retirement of Senior Staff, 1981-2001.[a]

	ACADEMIC YEARS				
	1981-1986	1986-1991	1991-1996	1996-2001	Total 1981-2001
Number of Openings Due to Death and Retirement	114	154	243	299	810
Number of openings Filled By Replacement Scenario[b]					
Low	39	53	84	103	279
Intermediate	64	87	137	168	456
High	89	120	190	234	633

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[a] Senior staff are defined as physics Ph.D.s employed as associate or full professors in 4-year colleges. Figures for the base year 1981 were derived from unpublished NAS data.

[b] It is assumed that the decline in the number of traditional age college males will adversely affect 4-year college staffs more than university staffs. In fact, the decline in undergraduate enrollment may result in the closing of physics departments in some 4-year colleges. The three scenarios (high, intermediate, and low) reflect the reduction of the total physics professoriate in 4-year colleges by 10, 20 and 30%, respectively. The data indicate the number of senior staff openings due to death and retirement that would be filled to achieve these reductions in overall physics staff.

We pose two basic scenarios for growth in nonacademic physics employment. The first scenario assumes a moderately paced economy reflecting nonacademic growth at approximately the levels that occurred during the 1973-1981 period. This growth would average 3% per year, which is consistent with the Bureau of Labor Statistics (BLS) intermediate projection for physicists through 1995. The second scenario assumes a somewhat slower-growing economy, reflecting a more conservative increase in nonacademic opportunities. Demand would be above replacement, but below that suggested in the prior scenario. This growth would average 2% per year. Based on expectations over the long term for an increasingly technological labor market calling upon sophisticated research and development skills, we feel that the moderate growth scenario is the most likely forecast.

Positions opened by physicists leaving the field are also an important source of future employment. Currently the net outmobility of physicists is nearly 1.5% a year. If the supply of physics Ph.D.s falls short of the demand, the level of outmobility may decrease despite a strong continuing pull into other fields. Thus the model poses two levels of net outmobility: moderate outmobility consistent with current levels, and low outmobility of approximately 1% a year.

Table S2-6 indicates the number of positions in physics expected to be open in the 1981-2001 period under these two basic scenarios. The potential demand for physics Ph.D.s in related areas of science and engineering is difficult to measure precisely because there is often only a fine line separating them from physics. Nevertheless, demand for physics Ph.D.s in these areas is also expected to increase in the next decade. Thus, there are several hundred potential nonphysics or interdisciplinary openings for Ph.D.s in addition to those described in the scenarios above.

S2.6.2 Supply Projections

Projections of supply depend upon a number of interdependent variables: the size of the age groups from which the supply is

Table S2-6

Employment Opportunities for Ph.D. Physicists Working in Physics Outside of Academe by Demand Scenario and 5-Year Groupings, 1981-2001.[a]

	1981-86	1986-91	1991-96	1996-2001
Conservative Growth (2% per year)				
Low Outmobility (1% per year)				
Replacement	803	939	1146	1362
New Openings	757	757	757	757
Total	1560	1696	1903	2119
Moderate Outmobility (1.45% per year)				
Replacement	963	1103	1305	1509
New Openings	757	757	757	757
Total	1720	1860	2062	2266
Moderate Growth (3% per year)				
Low Outmobility (1% per year)				
Replacement	803	960	1188	1428
New Openings	1136	1136	1136	1136
Total	1939	2096	2324	2564
Moderate Outmobility (1.45% per year)				
Replacement	963	1132	1364	1600
New Openings	1136	1136	1136	1136
Total	2099	2268	2500	2736

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[a] The conservative growth rate indicates the number of openings in a slowly growing economy.

The moderate growth rate is similar to the increase in demand in nonacademic positions observed between 1973 and 1981. It is also consistent with the BLS intermediate scenario for growth in demand for physicists through 1995.

The low outmobility rate reflects the lowest level that outmobility is likely to reach.

The moderate outmobility rate reflects the current net mobility of physicists into other fields.

Replacement refers to openings due to death, retirement, and net outmobility.

New Openings indicate the number of new positions due to growth in demand.

drawn, patterns of enrollments in higher education, choice of major, retention in the educational system, and career directions following receipt of the degree. Perceptions of economic and occupational demand also have an effect.* Long-term projections of possible changes are of particular import for physics, where the training pipeline frequently requires over 10 years. The physics Ph.D.s of the middle-1990's are formulating their initial career decisions now. We will first present short-range projections for the production of Ph.D. physicists and then venture into the relatively uncharted territory represented by the remainder of the 20th century.

Physics Ph.D. Production. Most of the new physics Ph.D.s of the late 1980's are already in the graduate school pipeline. Extrapolating from first-year graduate students at Ph.D.-granting departments, a best past-production predictor, we expect 6800 physics Ph.D.s to be awarded between 1984 and 1990.† Note should be made of the projected increase in the foreign component, a reflection of the dramatic increase in first-year foreign graduate students since 1979 (Figure S2-7).

Projections of Ph.D. production through the remainder of the century involve analysis of the education pipeline leading to graduate school. The group of 18- to 24-year-old males, from which traditional undergraduate physics majors and subsequent bachelors are drawn, will have decreased by over 20% by 1996. However, because of the increasing emphasis on the utility of a scientific background in tomorrow's

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*See, for example, R. Freeman, The Labor-Market for College-Trained Manpower, Cambridge, MA, Harvard University Press, 1971, and R. Freeman, "Supply and Salary Adjustments to the Changing Science Manpower Market: Physics, 1948-1973." American Economic Review 65: 27-39, March 1975.

†Physics Ph.D. students complete their programs in 4-9 calendar years respectively at the following rates: 3%, 7.5%, 14%, 11%, 6%, and 1.3%. Thus, on the average, approximately 43% of the first-year students eventually earn their Ph.D.'s. The last two years of the short-term projections were supplemented by extrapolations of first-year graduate students from junior majors using linear regression analysis.

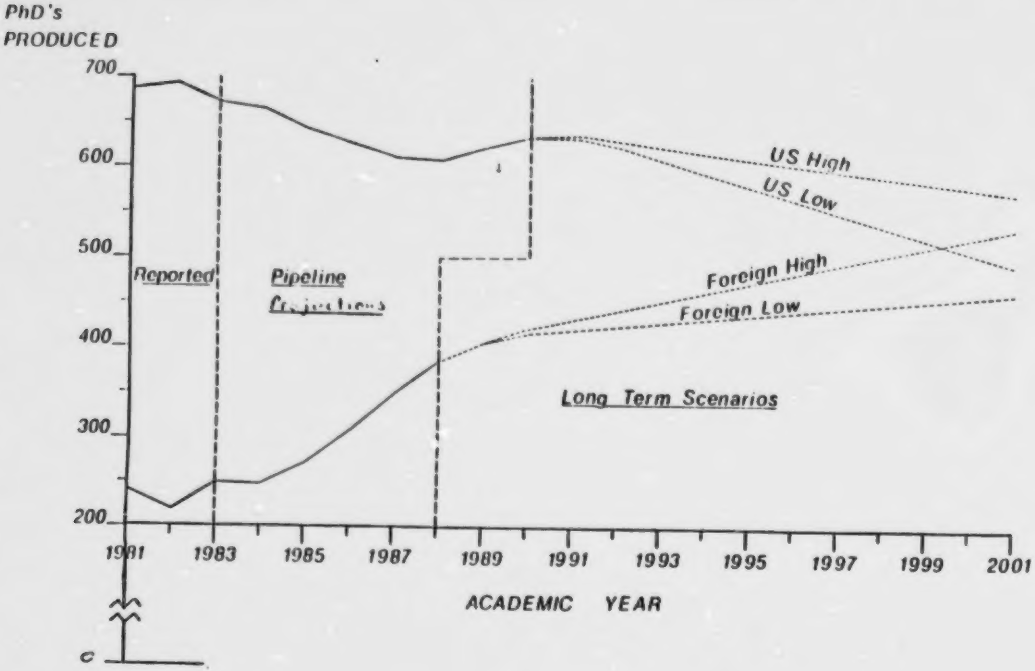

Figure S2-7. Physics Ph.D. Production by Citizenship, 1981-2001.

technological society, our probable scenario assumes a more modest decline in physics bachelors of 10% from current levels. This presupposes that steps will be taken to alleviate the deteriorating condition of precollege science education and that potential physics majors are, thus, not turned off from science in general before even entering college.

Approximately one-third of physics bachelor's recipients go on to physics graduate study. Another 15% of the first-year physics graduate students come from other disciplines. Our model assumes that the latter relationships will remain relatively stable in the future.

The participation of foreign graduate students, which has increased dramatically since 1979, will have an important influence on future Ph.D. production in physics. The scientific and technological needs of both developing and developed countries are expected to stay high during the remainder of the century. Our model thus assumes a growth in the number of foreign students of between 1 and 2-1/2% a year through 2001. The effect on Ph.D. production will depend on the graduate-school completion rate of these students. In the final years of the century, we project between 980 and 1100 total physics Ph.D.s a year (Figure S2-8). Under the most extreme scenarios, U.S. citizens around the end of the century may become a minority of the physics Ph.D. recipients.

Supply of Physics Ph.D.s: 1981-2001. Physics Ph.D. production does not equal supply. Two major factors which reduce this pool must be taken into account: immediate outmobility from physics, and the return migration of foreign degree recipients. Many physics Ph.D.s, traditionally about 20%, move into nonphysics employment within 3 years of their degree. This outmobility increased to 30% during the difficult employment market of the early and middle 1970's, and it has not shown any marked decrease since. The current high level, however, seems to be guided more by pull than by push factors. Our model assumes that this outmobility will move towards the more typical 20% level, as basic research opportunities in physics improve during the 1990's.

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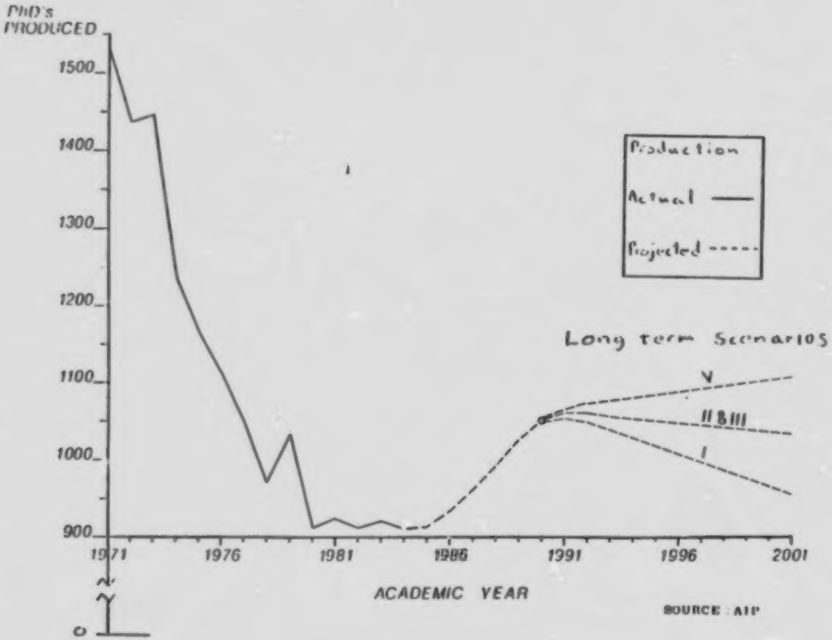

Figure S2-8. Physics Ph.D. Production, 1971-2001.

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The second factor affecting the supply of new physicists is the return home of new Ph.D.s who are foreign citizens. We estimate on the basis of past experience that one-half of these foreign nationals will return home, either immediately after receiving their degrees or following an ensuing postdoctoral or other temporary position. This phenomenon is sensitive to change. With the foreign component potentially approaching half of the Ph.D. production, such changes could have a major effect on the available supply. While U.S. citizen physics Ph.D.s are expected to decline, the supply of foreign Ph.D.s could double by 2001 (Table S2-7).

S2.6.3 The Demand-Supply Balance

Figure S2-9 illustrates the projected range for the supply of new physicists and the demand for Ph.D.s to work in physics. As discussed, forecasting either supply or demand involves many parameters, some unknowable. The shaded portions of the figure reflect our best estimates of the likely demand and supply levels during each of the four 5-year periods through the remainder of the century. We project a balance between likely demand and supply through 1991. Later in the 1990's, however, it appears that the supply of new physicists may not match the number of possible physics openings. If this mismatch occurs, increased competition among employers for well-trained physicists is likely.

The divergence between probable demand and supply may be even greater than we have indicated, because it does not include the projected increase in employment opportunities in the many neighboring scientific and engineering areas where physicists have always made contributions of major import.

S2.7 Conclusion

If the assumptions outlined in the previous pages hold over the remainder of the 20th century, we project a precarious balance between demand and supply through the early 1990's. Beyond that, there are likely to be more opportunities than new physicists to fill them. There

Table S2-7

Physics Ph.D. Production and Probable Supply by 5-yr Groupings, 1981-2001

Academic Years	Total Number of New Ph.D.s	Total Number of Foreign Ph.D.s[a]	Estimated Number Available to Labor Force[b]
Reported and Pipeline Projections			
1981-1986	4591	1296	2760-3150
1986-1991	5096	1985	2870-3280
Long-Term Scenarios[c]			
Low U.S. - Low Foreign			
1991-1996	5140	2170	2840-3250
1996-2001	4890	2280	2630-3000
Low U.S. - High Foreign			
1991-1996	5290	2320	2890-3310
1996-2001	5190	2580	2730-3120
High U.S. - Low Foreign			
1991-1996	5260	2170	2920-3340
1996-2001	5200	2280	2840-3250
High U.S. - High Foreign			
1991-1996	5400	2320	2970-3400
1996-2001	5500	2580	2950-3370

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[a] It is assumed that half of the foreign citizens will return home within 4 years of receipt of their Ph.D.s.

[b] This column indicates the number of Ph.D.s available after return migration of foreign citizens and immediate outmobility from physics of new Ph.D. recipients. The ranges in the above estimated supply reflect the effect of immediate outmobility rates varying from 20 to 30%.

[c] The long-term scenarios indicate Ph.D. production under the following probable range of changes in 1st-year graduate student enrollment in physics programs:

Low U.S.--1st-year physics graduate students who are U.S. citizens are assumed to decline by 22% between 1985 and 1997. This would closely track a projected 25% decline in the number of total BA's received by 22-year-old males, the traditional source of physics graduate students.

High U.S.--1st-year physics graduate students who are U.S. citizens are assumed to decline by 10% between 1985 and 1997. This would result if physics were to attract significantly more than current levels of the traditional pool of 22-year-old male BA's.

Low Foreign--1st-year physics graduate students who are foreign citizens are assumed to increase by 1% per year over current levels between 1985 and 1997.

High Foreign--1st-year physics graduate students who are foreign citizens are assumed to increase by 2-1/2% per year over current levels between 1985 and 1997.

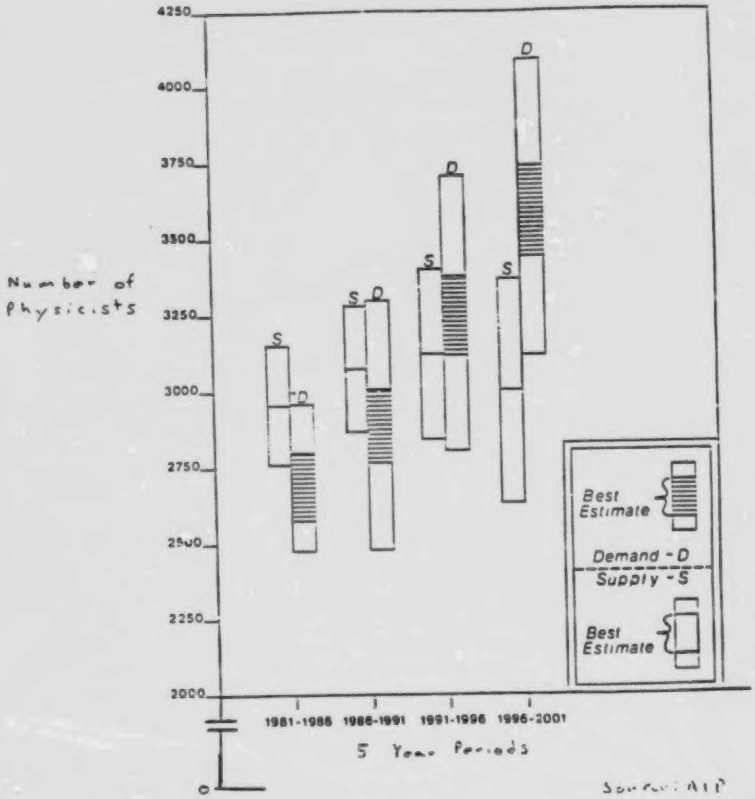


Figure S2-9. Projected Demand for and Supply of Physicists by 5-Year Period, 1981-2001.

will be keen competition among disciplines for the brightest students and among employers for new Ph.D.s. Under each of our scenarios, the physics labor force is seen as becoming increasingly dependent on non-U.S. citizens. With such a large leverage, any changes in the retention of the foreign component could have a strong effect on the overall demand and supply picture.

The rest of the century represents a rather broad span of time. The activities of the physics community, the Federal Government, and industry could certainly help to alleviate any pending shortages. The excitement inherent in physics and the opportunities for further research are great. It would be unfortunate if an insufficient supply of qualified physicists constricted these opportunities. Now is the time for the physics community to seriously consider means for attracting the bright students of tomorrow. In this effort, we must recognize that the largest untapped pool of potential new physicists can be found among those groups underrepresented in the past.

Mr. Walgren. Thank you very much. Let's then turn to Mr. Brown.

[A biographical sketch of Mr. Brown follows:]

Donald C. (Don) Brown

Donald C. (Don) Brown was born December 5, 1924 in Boston, Massachusetts. In 1945 and 1946 he served as an Ensign in the U.S. Navy. He received a B.S. degree in Chemical Engineering from the University of Texas in 1947. In college he was a member of the Phi Eta Sigma freshman honorary society, and a member/officer of Signa Nu social fraternity. He twice received a university award for "Best All-around Intramural Athlete".

Immediately after graduation from college he joined Sun Oil Company, now Sun Company, as an engineer trainee at Sun Field in South Texas. He later progressed through various engineering and management positions, serving in West, North, and East Texas. He moved to Dallas in 1965, where he has performed as Director of Field Operations, served on a merger diagnostic team, and then has been Manager of Compensation and Benefits, Chief Methods Engineer, Chief Operations Engineer, Chief Production Engineer, and Chief Evaluation Engineer.

As Chief Evaluation Engineer, from June 1983 through November 1984, he had management and technical responsibilities for implementation of an on-going divestment program for marginally economic leases, plants, pipelines, offshore platforms, and facilities in Sun Exploration and Production Company activities throughout the United States.

In his previous assignment as Chief Production Engineer, from June 1978 through June 1983, he had responsibilities for the production engineering activities and production engineering personnel of Sun Production Company throughout the U.S., along with coordinating responsibilities for various manpower planning activities relating to field hourly personnel, Production Engineering Technicians, and Engineering Staff Associates. He coordinated the permanent and summer engineering recruiting programs for Sun Production Company, working with personnel from Sun Gas Company and Sunmark Exploration Company, in their joint on-campus engineering recruiting activities.

After his retirement from Sun in December 1984, he established Don C. Brown and Associates to provide consulting services in the petroleum industry, with emphasis in the fields of management processes, production operations, drilling and completions.

Brown is a member of the American Petroleum Institute and of the Society of Petroleum Engineers of AIME, and is a Registered Professional Engineer in Texas. He has served on numerous committees and often in executive capacities with these organizations. He was Section Chairman for the SPE's East Texas Section. He is a Past Chairman and is now an ex-officio member of the SPE's Engineering Manpower Committee. He is now the SPE and AIME representative on the Engineering Manpower Commission of the American Association of Engineering Societies, Inc.

He has received special citations for his contributions to the Society of Petroleum Engineers and Junior Achievement. He has authored several published articles on well completion activity in West Texas geological basins, and on manpower planning and salary administration for engineers.

He has been active in Indian Guides, Boy Scouts, Junior Achievement, youth football and baseball, and the Richardson Texas Quarterback Club functions and committee.

Brown is married to the former Marjory Taylor of Indian Orchard, Massachusetts. They have three sons, Donald C. Jr. of Herndon, Virginia; Robert of Pasadena, Texas; William of Georgetown, Texas; and a daughter, Barbara (Mrs. David Weatherbie) of Dallas. The Browns reside at 906 Creekdale in Richardson, Texas.

STATEMENT OF DONALD C. BROWN, PETROLEUM CONSULTANT, DON C. BROWN AND ASSOCIATES, RICHARDSON, TX

Mr. Brown. Good morning. I would like to start out my discussion here by saying that while I am a Commissioner on the Engineering Manpower Commission and also a member of the Society of Petroleum Engineers Engineering Manpower Planning Committee, my views are expressed here today as my own and not as a member of those committees.

One point I would make to you is that you need to think out well anything you do in this area because there are major differences between science and engineering; there are major differences between the parts of engineering.

Let me tell you a little bit here about one facet of engineering, which is petroleum. When you talk about the engineering swings—high, low—in the number of graduates, if you go back to 1952, you can look at the periods since 1952 where the swings from total graduates are approximately from high to low in the ratio of three. There were about three times more graduates last year than there were the low during that period.

For petroleum engineering, if you look at last year versus the midsixties, you are looking at a factor of 10. There were 10 times more graduates last year than there were in the 1962-63 era.

When you look at the last 10 years and look at overall increase in B.S. level engineers that were produced, you are looking at less than a factor of two for last year as compared to 1974. For petroleum, you are looking at a factor greater than five. So there is a whole series of things you need to be aware of.

When you look at the percent increases for B.S., you are looking at an increase roughly approximating 86 percent overall. Petroleum was a 460-percent increase. Within petroleum, when you get down to the M.S., your M.S. overall was up about 34 percent, and for petroleum it was up 333 percent.

Then when you go to your Ph.D., you have a completely different situation. Your doctorate level overall declined. Your doctorate level in petroleum declined by 42 percent as against 4 percent in the overall numbers. There were, in addition, nine other disciplines in which there were declines in the Ph.D. levels.

All of these factors are dramatically complicated by consideration of the number of foreign nationals in percentages running from insignificant to more than 70 percent in some of the higher levels of some of these disciplines.

Now, what I would also tell you a little bit about as background, then, is that petroleum engineering is one of the highly specialized engineering fields, basically to serve the petroleum industry. When positions are available, over 90 percent of the petroleum engineering graduates would enter the petroleum industry. That is not saying all of the engineers entering the industry are petroleum engineers. Less than 50 percent of the engineers entering are petroleum engineers because the industry does hire a broad mix.

When you consider some of the factors that have driven changes within the numbers within the industry—they are the number of wells drilled, the number of wells operated, the factors for increased technology—and all of those are driven by the spread between prices for oil and gas and the costs associated with drilling and production.

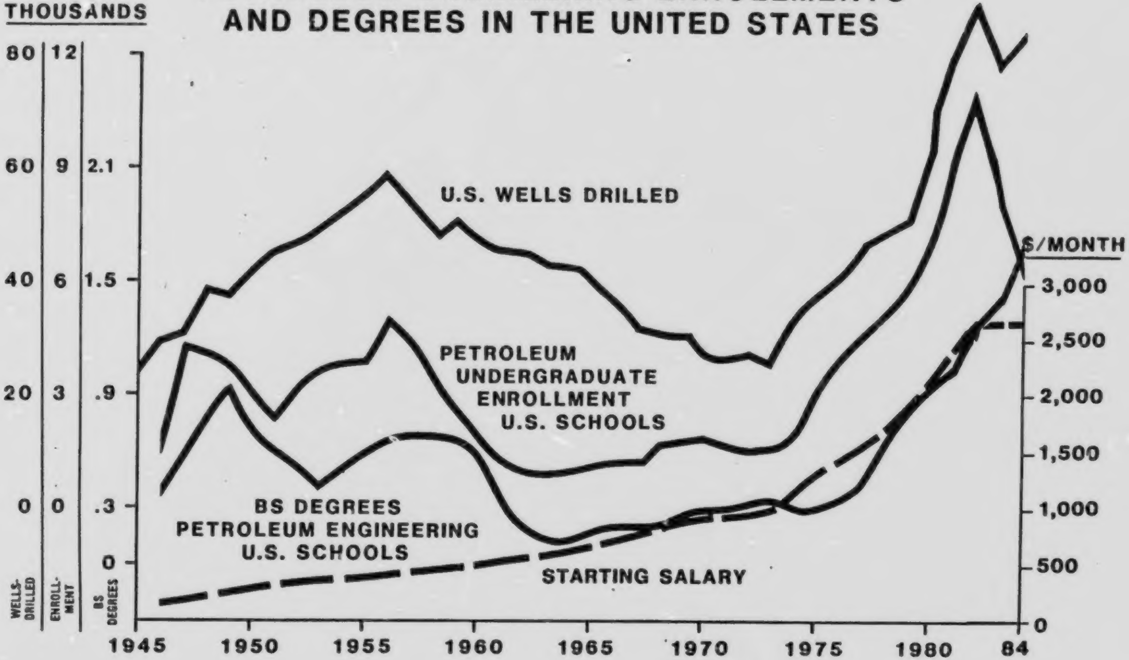
As you may well be aware, when you go back and compare 1973 to today, the price of crude oil has gone up from $3.89 a barrel in 1973 to a maximum of over $31 in 1981. It has now dropped to the point that it is $23.51 through February of this year. Gas prices dramatically escalated from 22 cents an MCF in 1973 to $2.63 in 1984, and that has now slightly declined to $2.57 this year.

The number of active wells that the industry has taken care of has dramatically increased from 484,000 back in 1947; it went up to about 620,000 by 1974; and it is now over 850,000, a dramatic increase in activities.

There is an exhibit in the testimony, exhibit 3, which shows the relationship of drilling to petroleum engineering enrollments and degrees in the United States. There is a great number of things to be gleaned from that.

EXHIBIT 3

RELATIONSHIPS OF DRILLING TO PETROLEUM ENGINEERING ENROLLMENTS AND DEGREES IN THE UNITED STATES



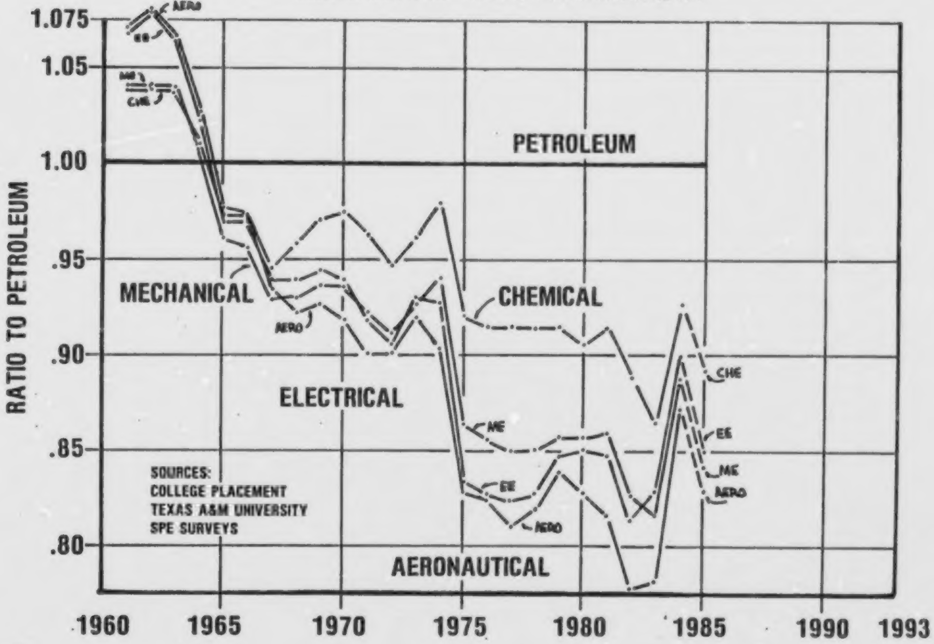
You will see that periods of dramatic oversupply of petroleum engineering graduates occurred in 1948 to 1951, again in 1956 to 1961, and now a third time from 1982 to date.

Note also the effect of compensation involved here. The start of the dramatic increase in enrollment in the fall of 1975 for petroleum engineers was fueled by a 22-percent increase in starting salaries for petroleum engineering graduates.

When you look at exhibit 4, which is engineers' starting salaries comparing different disciplines, you will see that things don't stay the same. In the early sixties, petroleum engineers received starting salaries 5 to 7 percent less than those received by aeronautical, electrical, chemical and mechanical engineers.

EXHIBIT 4

ENGINEERING STARTING SALARY OFFERS RELATIVE TO PETROLEUM



SOURCES:
COLLEGE PLACEMENT
TEXAS A&M UNIVERSITY
SPE SURVEYS

BEST COPY AVAILABLE

A few years ago, petroleum engineers were receiving starting salary offers 5 to 7 percent above those, and that has again dramatically increased to where the offers now for petroleum are anywhere from 11 to 17 percent above those disciplines.

Another factor that is extremely important, I think, has to do with the salaries of ongoing engineers. If you go back in history back into the early fifties and on through the 1974 era, there is a consistent cycle and ratio that says that if you look at the starting salaries in a year, the mature engineers that same year, 33 years out, are getting about twice as much in annual salary. It varies a little bit, but it doesn't vary much. That held true for petroleum engineers and the category as the Engineering Manpower Commission groups it of all engineers, and that includes Government, education, and industry.

By 1978, given the dramatic increases in petroleum engineering salaries, that thing was just about ready to start going askew. Starting salaries for petroleum engineers in 1978 were 18 percent above the average for the all-industry group. The ratio still held at two. What I am saying to you is that if you took the starting salary in that year and looked out at the 33-year group, you still had a ratio of plus two.

Now, for petroleum, that has continued to hold. But in 1982, it was 1.09; in 1983 it was 2.03; and there is an anomaly here in 1984 that starting salaries remained constant, mature salaries went up, and that ratio is 2.35. But there still is a lot of incentive for people to stay in petroleum engineering.

When you look at the other group, the all-engineering group, since 1978, that has not continued. The ratio of mature salaries to starting salaries has dropped to the point that in 1982 it was down to 1.76; 1983, it was 1.69; in 1984, it is 1.71. Now, that means that for people in the industry, in education, and in Government, there is less incentive to remain in those activities than there was a few years ago, and that is a considerable disincentive. There is data in the testimony that will let you see what the differentials were here.

When you are looking at petroleum engineering, you have got to be aware that there have been dramatic changes in the numbers of faculties. There were increases in the numbers in the late forties, early fifties, a rather steady erosion in numbers from the midfifties to the early seventies, and then a slight increase after that point in time. There are now only 23 schools offering B.S. degrees in petroleum engineering, plus two others which offer petroleum engineering options, and there are only 20 of those schools, plus three others, which offer graduate degrees. So you have a much smaller sample to look at and consider here.

Faculty staffing has gone through dramatic expansions up to the midfifties, a contraction from 1956 through 1973, and then dramatic growth from 1973 to date, most of which growth has actually happened in the last 5 years.

Given those backgrounds, it is hardly surprising that almost all of the U.S. petroleum engineering schools have numbers ranging from some to many of their faculty who either have less than a Ph.D., have degrees in disciplines other than petroleum engineering, and/or members who were foreign nationals when they received their degrees.

Salaries of the faculty members did not increase at the same rate as the starting salaries for the B.S. level of petroleum engineers, so that by 1981, B.S. level petroleum engineering students were being offered starting salaries higher than their doctorate new faculty. In 1981, a number of petroleum industry companies started special long-term programs to enable the departments to substantially supplement faculty salaries and to encourage U.S. citizens to seek advanced M.S. and doctorate degrees.

The continuing and/or expanded support of industry and the Federal Government is needed for graduate scholarships, fellowships, endowments, and for research, and that will be of special help in developing minorities and females in faculty positions.

The present status of the petroleum engineering discipline is at a point where only 40 percent of this year's graduates had or will have jobs firmly in hand when they graduate, where undergraduate enrollment has declined about 40 percent in the last 2 years. But at the same time, graduate enrollment is up substantially at the M.S. level, with higher numbers of U.S. citizens, and at the doctorate level, with more U.S. citizens, and where the heads of the departments are saying that those individuals, the U.S.-M.S. level and U.S.-Ph.D. level, are having absolutely no trouble in finding positions; and where departments are or will be under pressure to eliminate, consolidate, or reduce.

The future trends seem to be in the area of continued reductions in the number of B.S. level graduates over the next few years, and undergraduate enrollment will continue to decline. There will be more U.S.-M.S. and doctorate level degrees awarded. There will be fewer petroleum engineering departments, with more of the faculty having doctorates in petroleum engineering.

I will be glad to expand on any of this if there is time.

[The prepared statement of Mr. Brown follows:]

Prepared Statement of Donald C. Brown

GENERAL

My discussion today concerns the academic discipline of petroleum engineering in the United States, which has been subject to dramatic cycles of changing supply/demand over the past 40 years, and its relationship to the total U.S. engineering academic sphere.

ENGINEERING DEGREES/PETROLEUM ENGINEERING DEGREES

Figure 1, Engineering Degrees Earned 1952 - 1984 shows the total U.S. engineering degrees, by levels, earned over the past 33 years, during which period the annual total BS level graduates increased from some 30,000 to 77,000. There were significant declines from 1952-54, 1960-63, and 1972-76. Most of the increase, above the increase in 1955-59 and an overall trend increase, probably related to population growth, occurred in the last 8 years in going from some 38,000 to 77,000, for more than 100% growth. This figure and the tables in the Exhibits 1 and 2 were extracted from Engineering Manpower Bulletin 75, December 1974, published by the Engineering Manpower Commission (EMC) of the American Association of Engineering Societies (AAES).

Table 5, Bachelor's Degrees in Engineering, By Curriculum, 1974 - 1984, will show the differing rates of growth for the individual disciplines. Do note that the largest percentage change occurred in petroleum engineering in going from 299 to 1,587, up 430% in the period where the total change was 86%.

Table 7, Master's and Engineer Professional Degrees in Engineering, By Curriculum, 1974-1984, shows the changes by discipline in this grouping where the overall increase was up 34%, less than 40% of the percentage growth for the BS group. Note also that there were declines in aeronautical, engineering science, environmental, industrial nad manufacturing, and nuclear engineering. Petroleum again headed the list in percentage increase, in going from 60 to 260, up some 333%.

Table 8, Doctorate Degrees in Engineering, By Curriculum, 1974-1984 allows a study of the changes by discipline for this group which actually in total had a 4% decline; petroleum had a 42% decline, from 19 to 11, while the categories of aeronautical, chemical, electrical and electonics, engineering general, engineering science, mining and metallurgical, systems, and other engineering also showed declines.

PETROLEUM ENGINEERING/PETROLEUM INDUSTRY

The petroleum engineering discipline is specialized, basically to serve the petroleum industry in such fields as exploration, drilling, completion, workover, production operations, field and plant separation and treatment of oil and gas, pipelines, oilfield service, supply and manufacturing, economic analysis, planning, research, and education.

In times when positions are readily available, well over 90% of the petroleum engineering graduates would enter the petroleum industry, with only small percentages going into other professional fields such as business administration and legal, and into government, etc. Of those petroleum engineers entering the industry some 75% would initially accept employment with one of the major producers. The industry hires a broad mix of new engineering graduates, with less than 50% of the total new hires being petroleum engineers.

When you consider the factors to assess changing needs for engineers in the industry, simplistically the number of wells drilled might approximately represent the level of new work; the number of active oil and gas wells might represent the level of on-going work; factors for increased technology would have to be applied to both over a period of time; and all of these are driven by the spread between prices for oil and gas and the costs associated with drilling and production.

In the period 1973-1981, crude oil prices in the U.S. rose from $3.89 per barrel to $31.77; by 1984, this had dropped to $25.88; the 1985 average through February was $23.51. Natural gas prices increased from $0.22 per MCF in 1973 to $2.35 in 1982, with further increases to $2.63 in 1984. The 1985 average to date is about $2.57, which is down slightly.

In the period 1947-1957, total active oil and gas wells in the U.S. increased rapidly from 484,000 to 646,000. This was followed by slower increases to 695,000 through 1965, and then by a slow decline to 621,000 by the end of 1974. Since then the total has increased rapidly with today's total in excess of 850,000.

Exhibit 3, Relationship of Drilling to Petroleum Engineering Enrollments and Degrees in the United States shows these relationships from 1945 to date. The drilling data is from DOE; the enrollments and BS level petroleum engineering graduates are from SPE and from the EMC of AAES; the starting salary data is from Texas A&M University, SPE, and the College Placement Council, with data up to 1978 based on offers and after 1978 based on acceptances.

Periods of oversupply of petroleum engineering graduates occurred in 1948-1951, in 1956-1961, and from 1982 to date, with undergraduate enrollment starting to decline in the Fall following the school year in which some substantial number of graduates could not find industry jobs. Note also that the start of the dramatic increase in enrollment in the Fall of 1975 was fueled by a 22% increase in starting salaries for petroleum engineering graduates in the school year 1974/75, while other engineering disciplines showed starting salary increases in the range of 8% to 14%.

SALARIES - PETROLEUM ENGINEERING/PETROLEUM INDUSTRY/OTHER ENGINEERING INDUSTRY

Exhibit 4, Engineers Starting Salary Offers Relative to Petroleum shows the varying relationships that have occurred from 1961 to 1985. In 1961/1963, aeronautical and electrical graduates received starting salary offers some 7% above petroleum, while mechanical and chemical were up by some 4%. By 1967, they were all below petroleum by some 5.5 to 7%. Note the dramatic change from 1974 to 1975, with the larger differentials being maintained to the preliminary 1985 figures of below petroleum by some 11% to 17%. The source of this data was the same as for Exhibit 3.

Exhibit 5, All Engineers 1960-1984 Median Salaries of Engineers and Exhibit 6, Petroleum Industry 1960-1984 Median Salaries of Engineers can be used to show some interesting comparisons. The source for this data was the EMC of AAES. For both groups, from 1960-1974, starting salaries were reasonably close, and the salaries of the mature engineers with 33+ years of experience were each approximately twice the starting salary in that year. For 1978, the starting salaries for petroleum industry engineers were some 18% higher than the all engineers average; however, the ratio of final salaries to starting salaries still held for both groups at approximately 2.

From 1978 to 1984, petroleum industry starting engineering salaries rose rapidly to 1983 and have been relatively steady since. During the same period the salaries for petroleum industry mature engineers increased at close to the ratio of 2 times starting salaries, to 1982 at 2.09; to 1983 at 2.03; and then with 1984 starting salaries holding steady the ratio increased to some 2.35 for 1984.

From 1978 to 1984, the all engineering starting salaries rose at a substantial rate, (but somewhat less than the petroleum industry rate), but the salaries for the all engineering mature engineers increased only slightly faster than the starting salaries in this group. By 1982, the ratio was down to 1.76; for 1983 it was down to 1.69; and for 1984 it was 1.71.

SALARIES, SUMMARY/COMPARISON

What has happened, it appears, is that in much of the all engineering category made up of industry, government, and academic engineering, there has been a major change in salary administration for engineers with a resultant reduction in salary incentive as they mature, both as compared to the petroleum engineering/petroleum industry group and as compared to prior history in their groups.

Compared below are the median salaries which 1951 petroleum engineering graduates going into and staying in the petroleum industry might have had through time, as compared to the all engineering medians for other engineering graduates in 1951 going into other industries.

Year	Experience Years	PE Graduate Ann. Salary	All Engineering Ann. Salary	Ann. Diff. PE to all
1951	0	½ of $3,900	½ of $3,900	=
1960	9	9,100	9,550	-450
1966	15	13,500	13,750	-250
1970	19	17,500	17,600	-100
1974	23	23,500	22,600	+900
1978	27	36,000	31,700	+4,300
1982	31	61,600	42,400	+19,200
1984	33	73,900	44,600	+29,300

PETROLEUM ENGINEERING DEPARTMENT/FACULTIES

The discussion to this point has focused on the students and new graduates, and there is a need to discuss the U.S. petroleum engineering departments and faculties. In the late 1940's and early 1950's, additional schools were started to take care of the perceived increased need. With the enrollment declines in the period from 1956-1973, a number of petroleum engineering departments closed completely and others were combined with another discipline in order to continue. Since that time there have been several new departments started, to the point that there are now some 23 schools offering BS degrees in petroleum engineering, plus 2 others which offer petroleum engineering options with BS level degrees in other disciplines. At the graduate level, 20 of these schools, plus 3 others offer graduate degrees in petroleum engineering. During the period from the early 1950's to date, the number of international schools offering petroleum engineering has generally increased to the point that today there are at least 11 schools offering a BS degree or its equivalent, with 9 of these schools plus 2 others offering graduate degrees.

Faculty staffing has gone through expansions to the mid 1950's, contraction from 1956-1973, and dramatic growth from 1973 to date. Given the low number of petroleum engineering doctorates earned from the early 1960's on, the relatively high number of foreign nationals earning MS level degrees in U.S. schools (some 35-50% during the 1970's) and even higher numbers at the Doctorate levels (some 70%+ during the 1970's), it is hardly surprising that almost all of the U.S. petroleum engineering departments have numbers ranging from some to many of their faculty who have either less than a PhD, degrees in disciplines other than petroleum engineering, and/or members who were foreign nationals when they received their degrees.

The pay of the petroleum engineering faculty members did not increase at the same rate as BS level petroleum engineering salaries from 1974 to 1981, at which point BS level petroleum engineering graduates were being offered higher starting salaries than many of their new Doctorate level faculty. At that point, a number of petroleum industry companies started long term special programs to enable the departments to substantially supplement faculty salaries and to encourage U.S. citizens to seek advanced MS and Doctorate degrees, with the hopes of developing future faculty as well as more technologically advanced graduates for industry. The continuing and/or expanded support of industry and the Federal Government is needed at the university level for graduate scholarships/fellowships/endowments and for research, both to aid the present faculty and to develop those who will be on faculty in the future. This will be of special importance in developing minorities and women for faculty positions in petroleum engineering.

PRESENT STATUS

The present status has the petroleum engineering discipline at a point where only 40% of this year's BS level graduates had a job when they graduated, and that's up slightly from last year's 33%; where undergraduate enrollment has declined about 40% in the past two years; where graduate enrollment is up substantially at the MS level, with higher numbers of U.S. citizens, and up at the Doctorate level with some more U.S. citizens; and where the departments are or will be under pressure to eliminate, consolidate, and/or reduce departments/faculty.

FUTURE TRENDS

The future trends would appear to be continued reductions in the number of BS level graduates over the next few years, probably to the point that the pendulum will swing far beyond the point of balanced supply and demand; where the undergraduate enrollment will probably decline each fall until there are no substantial numbers of graduates unable to find industry jobs in the year preceeding; with more U.S. MS and Doctorate level degrees awarded; and where there will be fewer U.S. petroleum engineering departments, with more of the faculty having Doctorates in petroleum engineering.

EXHIBIT 1

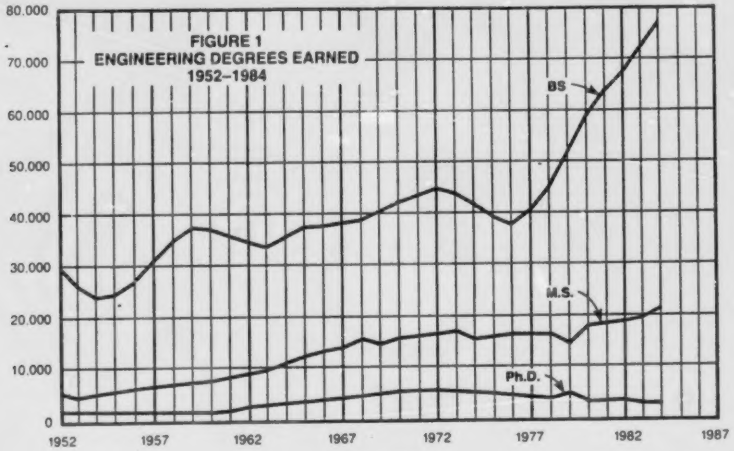


TABLE 5

BACHELOR'S DEGREES IN ENGINEERING, BY CURRICULUM, 1974-1984

Curriculum	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984 ✓
Aerospace	1041	879	793	897	977	1145	1376	1587	1731	2207	2364 ✓
Agricultural	450	365	453	443	559	619	779	666	711	704	655 ✓
Architectural	320	323	293	322	394	396	413	474	469	568	341 ✓
Biomedical	174	155	231	257	389	408	403	496	541	577	611 ✓
Ceramic	156	138	142	136	156	216	237	291	260	294	361 ✓
Chemical	3523	3167	3146	3593	4621	5837	6555	6863	7039	7499	7685 ✓
Civil	8176	7957	7947	8248	9168	10030	10191	10547	10330	10484	9877 ✓
Computer	727	599	796	1280	1546	1510	1816	2356	2666	2643	3499 ✓
Electrical & Electronic	11347	10277	9954	9837	10702	12213	13594	14558	16094	18590	20495 ✓
Engr. General	1716	1532	1665	1588	1744	2065	2029	2169	2360	1923	2037 ✓
Engr. Science	950	912	1022	990	955	1033	1114	1067	1641	1298	2349 ✓
Environmental	129	170	223	235	269	284	232	248	254	292	301 ✓
Industrial & Manufacturing	2510	2096	1826	1805	2054	2433	2710	3225	3695	3808	3923 ✓
Marine, Naval Arch. & Ocean	568	607	567	554	703	792	794	854	698	699	739 ✓
Materials & Metallurgical	580	539	568	611	706	829	1045	1081	914	1085	1011 ✓
Mechanical	7612	7076	6825	7549	8786	10076	11916	13462	14178	16484	17214 ✓
Mining & Mineral	460	444	456	545	721	868	1001	1054	1078	1019	978 ✓
Nuclear	339	333	403	494	576	534	529	444	426	420	434 ✓
Petroleum	299	309	359	408	617	812	915	1031	1256	1420	1587 ✓
Systems	153	191	177	188	199	199	211	235	346	210	222 ✓
Other	177	141	124	112	249	299	257	227	303	247	248 ✓
Total	**41407**	**38210**	**37970**	**40095**	**46091**	**52598**	**58117**	**62935**	**66990**	**72471**	**76931** ✓ ✓

EMC, Engineering Manpower Bulletin, December 1984.

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EXHIBIT 2

TABLE 7

MASTER'S AND ENGINEER PROFESSIONAL DEGREES IN ENGINEERING, BY CURRICULUM, 1974-1984

Curriculum	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Aerospace	554	466	431	439	408	381	406	390	492	512	553
Agricultural	144	125	139	140	117	133	156	157	144	146	189
Architectural	30	24	30	21	21	20	52	53	42	30	35
Biomedical	127	137	167	179	184	205	211	184	199	178	211
Ceramic	46	53	49	55	43	48	34	54	55	55	87
Chemical	1053	1050	1072	1177	1228	1151	1314	1326	1285	1509	1570
Civil	2681	2916	3069	2976	2755	2825	2835	3042	3046	3317	3351
Computer	723	678	718	802	986	1074	1262	1301	1371	1420	1533
Electrical & Electronic	3702	3587	3782	3674	3475	3335	3736	3845	4281	4730	5393
Engr. General	626	520	738	689	639	669	617	727	649	670	887
Engr. Science	576	536	581	507	560	482	529	489	634	408	434
Environmental	577	494	519	580	521	445	518	487	412	456	424
Industrial & Manufacturing	1502	1569	1433	1516	1387	1369	1510	1608	1441	1410	1262
Marine, Naval Arch. & Ocean	160	174	222	185	160	173	180	174	202	163	186
Materials & Metallurgical	402	414	419	415	479	482	469	453	507	563	583
Mechanical	1999	1994	2077	2064	1910	2026	2181	2495	2573	3001	3160
Mining & Mineral	127	104	136	162	188	183	195	151	207	280	242
Nuclear	391	416	460	488	482	408	368	311	317	311	282
Petroleum	60	76	98	94	112	125	134	161	147	227	260
Systems	353	406	332	381	404	415	465	437	490	430	469
Other	52	34	34	27	123	87	57	69	49	93	105
Total	15885	15773	16506	16551	16182	16036	17229	17914	18543	19909	21226

TABLE 8

DOCTORATE DEGREES IN ENGINEERING, BY CURRICULUM, 1974-1984

Curriculum	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Aerospace	168	159	136	138	114	93	93	114	103	97	131
Agricultural	51	49	33	27	36	55	67	52	43	51	69
Architectural	0	2	3	0	0	0	0	1	0	0	0
Biomedical	38	52	49	54	59	49	54	54	43	50	49
Ceramic	17	15	15	16	17	20	17	18	12	18	18
Chemical	403	366	333	301	259	309	304	312	319	379	380
Civil	393	364	382	328	284	297	294	357	368	390	402
Computer	83	107	90	136	123	190	159	171	129	102	131
Electrical & Electronic	700	673	644	574	524	545	523	503	549	608	693
Engr. General	136	116	114	96	86	112	98	123	114	76	55
Engr. Science	279	272	233	240	212	238	211	187	256	170	151
Environmental	61	44	55	60	36	49	53	49	68	68	79
Industrial & Manufacturing	119	120	112	113	97	116	109	109	98	108	124
Marine, Naval Arch. & Ocean	18	14	17	19	21	24	18	22	16	18	21
Materials & Metallurgical	220	226	204	222	213	181	227	206	196	228	241
Mechanical	446	361	345	300	304	335	307	339	341	399	476
Mining & Mineral	34	28	26	24	30	21	35	45	32	54	33
Nuclear	100	80	129	107	94	102	107	112	127	114	115
Petroleum	19	20	15	20	19	22	21	13	23	14	11
Systems	60	56	31	38	40	42	52	48	44	56	49
Other	19	14	11	5	5	15	4	6	6	3	6
Total	3362	3138	2977	2814	2573	2815	2753	2841	2887	3023	3234

EMC, Engineering Manpower Bulletin, December 1984.

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EXHIBIT 3

RELATIONSHIPS OF DRILLING TO PETROLEUM ENGINEERING ENROLLMENTS AND DEGREES IN THE UNITED STATES

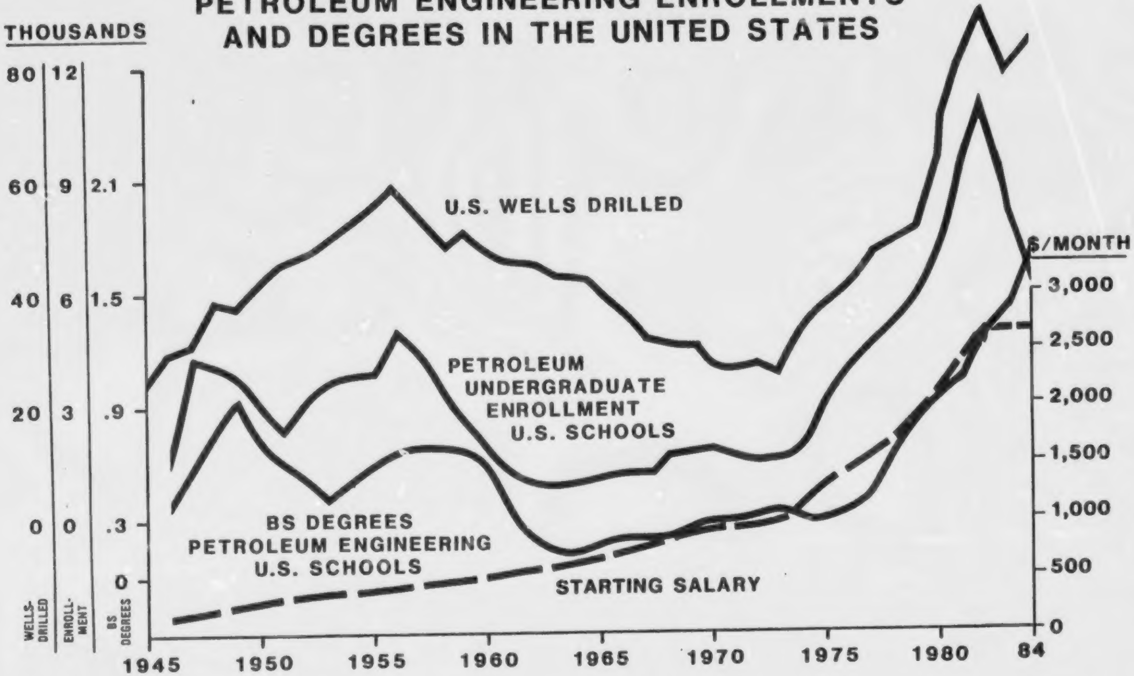
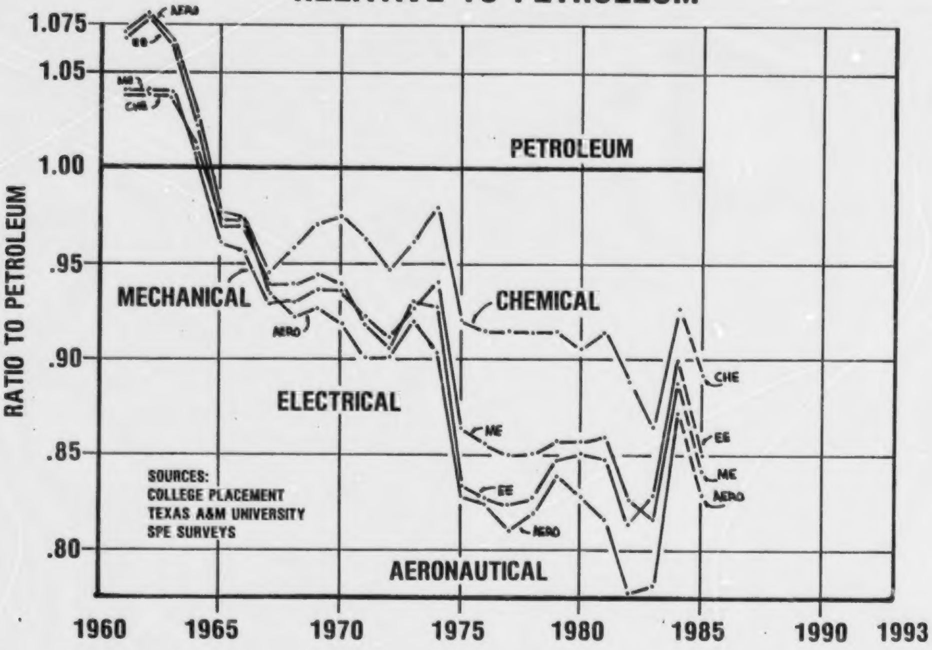


EXHIBIT 4

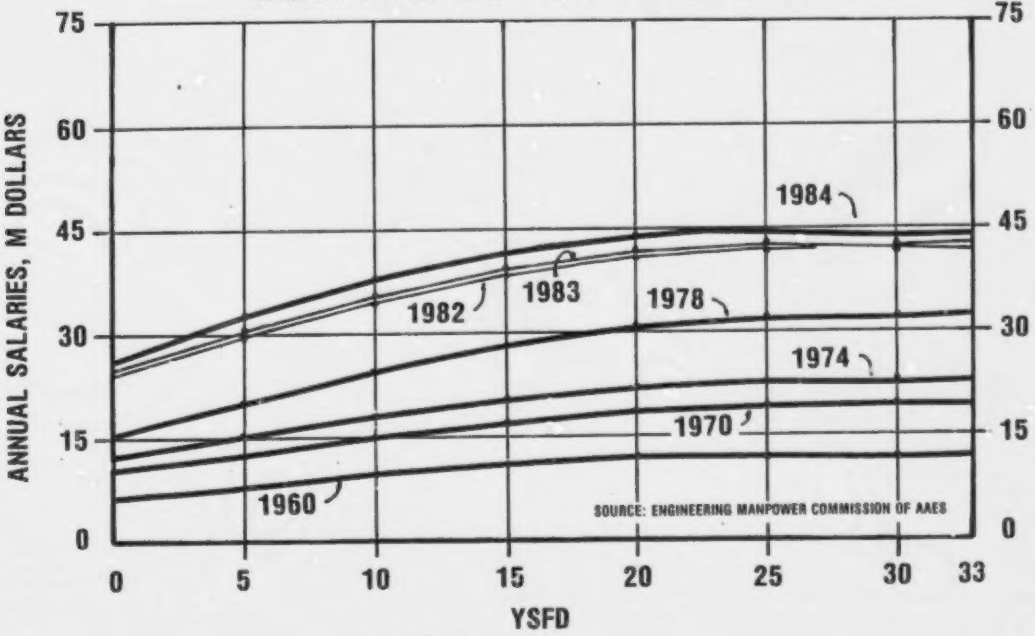
ENGINEERING
STARTING SALARY OFFERS
RELATIVE TO PETROLEUM



135

EXHIBIT 5

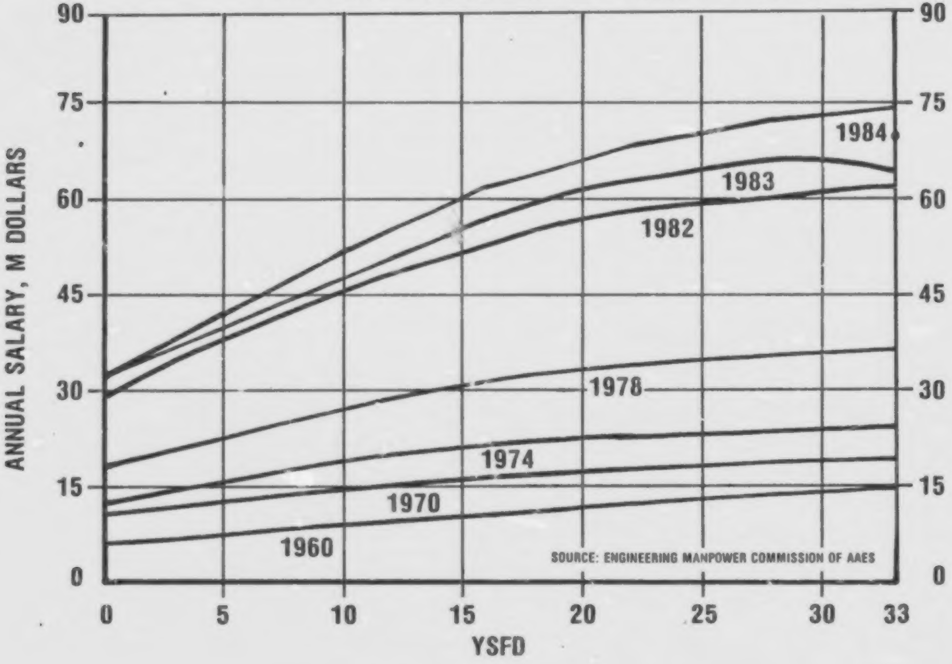
ALL ENGINEERS 1960-1984
MEDIAN SALARIES OF ENGINEERS



SOURCE: ENGINEERING MANPOWER COMMISSION OF AAES

EXHIBIT 6

PETROLEUM INDUSTRY 1960-1984
MEDIAN SALARIES OF ENGINEERS



SOURCE: ENGINEERING MANPOWER COMMISSION OF AAES

Mr. **Walgren**. Thank you very much, Mr. Brown.
Let's turn to Mr. Reed.

STATEMENT OF BILLY E. REED, PRESIDENT, AMERICAN ENGINEERING ASSOCIATION, FORT WORTH, TX

Mr. **Reed**. I will be as brief as I can. I appreciate the opportunity to have the views of what we call the working engineer expressed here.

Our membership basically is the people who work at the nuts-and-bolts level of the engineering profession, mainly in aerospace and electronics.

It is our basic view that there is no engineering shortage and that there has not been an engineering shortage. We will get that out right away. Virtually all of the information that I am sure you all have received has come from industry and has come basically from an organization called the American Electronics Association.

They arrived at their conclusions in a very simple way: they surveyed themselves. So it should not be surprising that the results that they get are the results they want.

Nearly all the projections for shortages or surplus or whatever, including some by the National Science Foundation, have used the American Electronics Association data. There is another thing that that data has in common: they have all overestimated the demand, and they have grossly underestimated the supply.

A good example of that is that the American Electronics Association estimate of the number of BSEE's for the years 1983 through 1987 range from 13,100 to 13,900. The actual number of graduates in 1983 was 18,590, and only with the most optimistic projections was NSF able to come any closer. They had 15,900 under their most optimistic projections of need. The 1983 fall enrollment, undergraduate enrollment, for electrical engineering was 106,000, which should translate to something in the order of 22,000 to 25,000 graduates per year.

The entire system for determining demand appears to be based on the word and integrity of the employers. Commenting on that, a recent article in a major electronics trade journal carries a headline, "Thirty-six Defense Contractors Under Criminal Investigation." At least 20 of those 36 are members of the American Electronics Association, so I think it is necessary to put that in perspective.

One of the most obtuse arguments that I have seen offered for a shortage as proof of a shortage of engineers is that the cost of recruitment has gone up. The cost of everything has gone up in recent years.

Another answer to that is that corporations are able to interview more people for each position. An example of that is McDonnell-Douglas, who recently interviewed 4,039 new graduates for 183 positions. That doesn't look like a shortage to me, but it certainly could explain the high cost of recruitment.

None of the surveys that we see considers any response to any perceived shortage except training more engineers. We believe that there are quite a few valid alternatives to training more engineers, and these include, but are not necessarily limited to, better utilization of the engineers that are within industry; use of "in-mobile" workers; paid overtime, which most employers refuse to do; employment of temporary engineers; and retention of the engineers leaving the profession each year and attracting those who never come into the profession each year.

We believe that any one of these alternatives could effectively virtually eliminate any perceived shortages. As examples of what I have just stated, DCAA found that the engineering work force at Boeing Company was engaged in nonproductive activities 39.4 percent of the time. The industry standard is supposed to be 10 percent. Now, my experience in the aerospace industry indicates that the Boeing situation is much closer to reality than what the 10 percent figure is.

A study by the American Association of Engineering Societies revealed much the same story but from a little bit different aspect, and that is that they looked at the ratio of support people or staff people to engineers and found that the ideal ratio would be four staff persons per engineer. When they looked at industry, they found that the ratio was approximately one to one, with the range being from four engineers per support person to slightly more than one engineer per support person, depending on which industry you were in.

A survey of engineers themselves that was conducted recently, in the last year or so, shows that nearly 50 percent of the aerospace engineers feel that they are underemployed; nearly 30 percent of the EE's felt that they were underemployed.

The Bureau of Labor Statistics indicates that 20 percent of the engineering graduates never enter the field. Another group roughly equivalent to 20 percent of each year's graduating class leaves the field.

NSF has stated in fact that occupational mobility—in other words, using a physics person as an engineer—could in fact alleviate any shortages that have been experienced. This is the only statement, incidentally, by any of these types of individuals that has even remotely hinted at another solution to an engineering shortage.

About 3 weeks ago, Erich Bloch, Director of the National Science Foundation, stated that he doubted projections of an engineering shortage. He said there may be some temporary shortages, but they are self-correcting. The system is robust. A shortage of any commodity brings with it an increase in price as measured in terms of real or after-inflation dollars. This simply has not occurred in the engineering shortage.

There is a practice in industry called salary rate control in which there is a planned replacement of older, therefore more expensive, engineers with new graduates or younger engineers. The phenomenon of salary compression is, I believe, a result of this practice.

We feel that there is nothing more detrimental to the engineering profession than industry's ability and willingness to import foreign labor. Most of the people who have been here arguing for restraints on foreign competition are importing foreign engineers about as fast as they can process the paperwork. Under current and proposed immigration law, it is not possible to prevent a foreign engineer from entering the country and taking a job that an American could fill.

Academia would have us believe that the world's best and brightest basically are all from somewhere else. Early in 1983, they were before Congress to solve the engineering crisis and testified they had to have access to the world's best and brightest, regardless of the country of origin. During that period of time, they requested funds to enlarge the schools, to produce more engineers. They were turning away U.S. citizens from these schools because of overcrowded conditions and, at the same time, they were recruiting students from overseas. The fields that they were basically using to recruit were, of course, engineering, science, mathematics, and computer science. They neglected to tell anyone that there were already as many or more foreign students in the schools than there were all U.S. minorities combined, if you exclude women.

I think it is important to point out that our colleges and universities rely heavily on financial support of industry. They receive grants, gifts, and cash and equipment from industry. The least they can do is provide a few thousand foreign graduates who are willing to work for less than their U.S. citizen counterparts. After all, we do need access to the world's best and brightest.

Recent calls for a freeze in salaries of all defense workers by some Members of Congress will have very negative effects for attracting engineers into that industry. It is not the salaries of the workers that need to be frozen; it is the markup, the overhead, and so on above the salaries that needs to be frozen. This is where the major cost comes from.

One practice of the Federal Government which I believe, if not illegal, is certainly unethical is the participation of the Los Alamos and Lawrence Livermore National Laboratories in a salary cartel which is known as the "R&D Group." Topics of conversation at the 1984 meeting included salary reduction plans and discussing the effects of the Simpson-Mazzoli immigration bill. The discussion basically centered on the recruitment of technical employees from overseas. While the group themselves denied that they discussed future salaries, one GE official was quoted as saying, "We swap salary data with about 30 other companies. From this data, we determine where we are and where we want to go." I cannot believe that that practice will have any positive effect on the supply of engineers.

I want to thank you for your willingness to have me here, and I will answer questions.

[The prepared statement of Mr. Reed follows:]

TESTIMONY

of

THE AMERICAN ENGINEERING ASSOCIATION

as presented to

GOVERNMENT & SCIENCE TASK FORCE

of

THE COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

HEARINGS ON SCIENTIST & ENGINEERS: SUPPLY & DEMAND

JULY 9, 1985

INTRODUCTION

The American Engineering Association is a non-profit corporation with membership in virtually every high-tech center in the United States. We are dedicated to the enhancement of the engineering profession and to support activities to enhance the employment opportunities of engineers and related professions.

We were founded in 1979 on the premise that United States citizens should have preference for jobs created and existing in the United States. All of our efforts since that time have been dedicated to that purpose.

We believe that our nation must maintain its technological leadership and must do so with United States citizens. To rely on foreign technology or foreign technologists carries with it a far greater threat to this nation than our reliance on foreign oil.

It is to this end that we offer the following testimony.

SHORTAGE?

The subject of a shortage of engineers is a subject in which there is little in the way of unbiased information. Nearly all of the information that Congress and the public receives is produced by those with a vested interest in having a shortage.

It is in the interest of the corporations to perpetuate the shortage stories very simply because a "shortage" inspires high school and college age youth to study engineering in huge numbers creating a surplus of engineers which translates to lower salaries, more people to choose from and more control of their employees. It is in the interest of academia to perpetuate the shortage stories because it translates into more students and more grants and therefore more income, security and prestige for the school.

At the center of the controversy over the shortage or surplus of engineering and technical talent is the American Electronics Association. Their much criticized surveys have been the basis of virtually all of the publicity of the "crisis level shortage" stories.

Certainly, a look at how they determined there was such a crisis shortage would be in order. The American Electronics Association's data comes from surveys made in the late 1970's or early 1980's. The surveys were made of the member corporations of the American Electronics Association; THEY SURVEYED THEMSELVES. Is it any wonder the survey reflected the story they wanted told?

An important point when considering these surveys is that they basically dealt with the electrical and computer engineering professions. Some how this data was marketed as a shortage of all engineers, not a shortage of electrical and computer engineers only. presumedly this was just an oversight on the part of the American Electronics Association.

Just as the surveys overestimated the demand, they have grossly UNDERESTIMATED THE SUPPLY side of the equation. For example, the American Electronics Association estimates of the new BSEE graduates for each of the years of 1983 to 1987 ranged from a low of 13,100 to 13,900. The NSF estimates for the year of 1987 were only 15,900 for their most optimistic projection.

THE ACTUAL NUMBER OF BSEE GRADUATES FOR 1983 WAS 18,590. The 1983 fall enrollment of electrical engineering students for all full-time undergraduate study was in excess of 106,000. [REFERENCE #1] That is an average of over 26,000 new electrical engineers for each of the next four years and the numbers are still growing.

Mr. Michael McPherson, moderator of a symposium held by the National Research Council titled "symposium on Labor-Market Conditions for Engineers" made the following statement in the concluding remarks "...the American Electronics Association study, which is something of an outlier, does have some important methodological weaknesses that were identified in the discussion and commentary at the symposium. THERE IS, I THINK, THEREFORE GOOD REASON TO DISCOUNT THOSE RESULTS." [REFERENCE #2]

One of the most obtuse arguments offered as proof of a shortage of engineers is that the cost of recruitment has gone up over the last few years, therefore, there must be a shortage of engineers. The obvious answer to that argument is that all costs have gone up over the last few years. Another answer is that the corporations are able to interview many more people for each position therefore the costs have gone up. McDonnell Douglas for example was recently (1983) able to interview 4039 new grads for 183 positions. This is hardly indicative of a shortage but it could explain the high cost of recruitment. [REFERENCE #3]

Another of the often quoted indicators is the Deutsch Shea & Evans High Technology Recruitment Index. This system is based on counting want ads (not job openings) in some 26 newspapers in 22 cities and 14 trade journals and engineering society publications. At best this method is an indicator of what DEMAND WAS, not what demand will be. To the best of my knowledge, DS&E has never hinted that their index was an indicator of future demand. This method is as flawed as AEA's survey of themselves though.

The premise of this method is that it samples the LOCAL demand for the cities indicated as well as the NATIONAL exposure by the trade journals and technical society publications. Any company could reasonably advertise in any or all of the cities and trade journals covered by the DS&E survey. presumably their ad would be counted each time it appears. This is a system that could be grossly distorted by a few very large corporations with the budget to advertise in several of those select places.

As with the original AEA survey, this method can easily have several different companies advertising for people to work on the next generation garbage disposal, for example, but the contract will only be awarded to one contractor.

Another obvious problem with this method is that if an employer wishes to employ a non-citizen, the employer MUST, BY LAW, ADVERTISE THAT POSITION EVEN THOUGH THE JOB IS CURRENTLY OCCUPIED BY AN ALIEN. THEY MUST ADVERTISE FOR A JOB THAT IN REALITY DOES NOT EXIST.

The entire system of determining demand is based on the word and integrity of the corporation answering the survey or placing the advertisements I think it is important to point out that a recent article in a major electronics trade journal carries the headline "36 Major Defense Contractors Under Criminal Investigation". [REFERENCE #4] At least twenty of that thirty six are very powerful members of the American Electronics Association.

The morality that allows a corporation to make false claims on their billing or take kickbacks from their subcontractors, knowing they are subject to criminal penalties, certainly would have no qualms about their statements concerning an engineering shortage or the need to import foreign workers, considering there are no penalties, either civil or criminal. The payoff is probably greater here too. AS WITH ANY CORPORATE POLICY, CORPORATE MORALITY IS DICTATED FROM THE TOP DOWN, NOT FROM THE BOTTOM UP!

THERE IS NO SHORTAGE OF ENGINEERS! In support of this position, I offer the following arguments.

First and perhaps most important, a shortage of any commodity brings with it an increase in price as measured in terms of real or "after inflation" dollars. This simply has not occurred with the "engineering shortage". Since nearly everyone will agree that electrical engineers are the closest to being in short supply, we will base our argument on that profession.

The latest salary survey of the Institute of Electrical and Electronic Engineers (IEEE) states that "Since the 1979 survey, EEs' income have increased 33.8% whereas the Consumer Price Index has increased only slightly more than 49%. This represents about a 15.2% DECREASE IN PURCHASING POWER." (Emphasis added) This survey is dated 1983 and released in 1984. [REFERENCE #5]

A very recent trade journal survey confirms this data when it states that "The mean (average) salary in 1985 for all respondents........an increase of (increased) 3.2 percent over last years.... The modest gain was offset by a rise in the Consumer Price Index of 3.7 percent since April of 1984, MEANING THAT THE PURCHASING POWER OF ENGINEERS FAILED TO KEEP UP WITH RISING PRICES." (Emphasis added) In the survey, engineering managers received raises of 7.8 percent while design (working) engineers received an average salary increase of only 1.2 percent before inflation. [REFERENCE #6]

There is a practice in industry called "Salary Rate Control" in which there is a planned, replacement of older, therefore more expensive, engineers with new graduates. The much publicized phenomenon called "salary compression" is a result of this practice. THIS PRACTICE CANNOT COEXIST WITH A TRUE SHORTAGE OF ENGINEERS.

It works something like this: An engineer reaches the age of 30 to 35, has been with the company for ten or fifteen years, becomes eligible for the retirement plan etc., and the raises he has become accustomed to gradually deteriorates until about the age of 50. He realizes that he is not treated as well as he was when he was younger. The jobs he is given to do are very mundane and lacks challenge. Any high school grad could do his job. He suddenly realizes that the new grads his company is hiring receives starting salaries only a few thousand dollars a year less than he makes after twenty or thirty years with the company.

Raise time comes up and he receives nothing. He takes early retirement. The company hires a new grad to replace him at six thousand dollars less that he was making. The company saved his raise, six thousand dollars a year and a large percentage of the retirement because he retired early. In addition they will not have to give the new grad a raise for a year.

If a shortage existed you would see PREMIUM PAY for overtime for all engineers. Few engineers today are paid more for their overtime hours than for their straight time hours if they are paid for overtime at all.

If there were a real shortage of engineers you would see virtually a total utilization of those people within their areas of expertise. Three recent studies shed some light on this aspect of the problem.

The Defense Contract Audit Agency (DCAA) looked at the productivity of the Boeing Company's engineering staff and concluded that "..the company's engineering workforce was engaged in non-productive activities 39.4% of the time when the aerospace industry standard relaxation allowance is only 10%." "Boeing has denied access to records." [REFERENCE #7]

The American Association of Engineering Societies (AAES), an umbrella group whose membership consists of many of the technical societies, has concluded that for optimum utilization of technical manpower that the ratio of support personnel to engineers should be 4:1. (4 draftsmen, technicians etc. for each engineer.) They found however "...that the ratio is less than 1:1 throughout industry."

The report goes on to state that "Adequate staff support is considered essential to free engineers from routine matters and give work that challenges their capabilities. Nonetheless, industry persists in limiting work assignments and distorting the hierarchy of the engineering team. Evidence of this fact is borne out in the ratios of engineering technicians to engineers in five industries: 0.24:1 in guided missiles and space vehicles, 0.39:1 in aircraft and parts, 0.51:1 in communications equipment, 0.94:1 in measuring and control instruments and 0.94:1 in office and computer machinery." [REFERENCE #8]

A study by the Research Group for Human Development and Educational Policy reached the following conclusions "About 32.7 percent of all students who entered college in 1970 and graduated in engineering disciplines consider themselves underemployed..."

"Underemployment figures for engineering disciplines according to the study are:
- Aeronautical engineering 50 percent
- Civil engineering 31.4 percent
- Industrial engineering 47.1 percent
- Mechanical engineering 36.4 percent
- Electrical engineering 28.6 percent" [REFERENCE #9]

The Bureau of Labor Statistics indicates that about 20% of the engineering graduates NEVER ENTER THE FIELD. Another group roughly equivalent to 20% of each years graduating class LEAVES THE FIELD EACH YEAR. [REFERENCE #10] If there were a true shortage of engineers, industry would find a way to retain those leaving and attract those who never enters the field. This would be a very cost effective way to gain thousands of appropriately trained engineers each year.

If there were a shortage of engineers there would be a very large utilization of the so called "in-mobile" workers; graduates of other fields such as physics, chemistry, mathematics etc. who are attracted to the engineering field by the higher salaries. With little or no retraining many other fields may easily be adapted to the engineering environment. This is one of the traditional ways to increase the numbers of engineering personnel. It has the added benefit of relieving other professions of their "over-abundance" of workers. There has been criticism of the in-mobile worker as being generally unqualified; yet such defense and space programs as Mercury, Gemini, Apollo, the Space Shuttle, the F-16, F-15, F-18, F-111, B52, B1 and others have all relied heavily on these workers for many years without adverse affects.

On the subject of engineering shortages, a recent trade journal article states that "The director of the National Science Foundation (NSF) said recently that he doubted projections of an engineering shortage.". The article goes on to say "Bloch told EE Times after his speech that there is not a "chronic shortage" of engineers. There may be some temporary shortages but they are self correcting, he said. "The system is robust."" The article states "...he believes there is not enough engineering faculty. But he added, "I am less convinced of the advertised engineering shortage in general."" [REFERENCE #11]

FOREIGN WORKERS

Other than the inherent cyclical nature of the engineering profession, there is nothing more detrimental to the engineering profession than industrys' ability and willingness to import foreign labor. Most of the same people who have been here arguing for restraints on foreign competition are importing foreign engineers as fast as they can process the paperwork. UNDER CURRENT AND PROPOSED IMMIGRATION LAW, IT IS NOT POSSIBLE TO PREVENT A FOREIGN TECHNICAL WORKER FROM ENTERING THE COUNTRY AND TAKING A JOB THAT AN AMERICAN COULD FILL.

The foreign worker is in direct competition with the American contract engineer on a one to one basis. Each foreign worker allowed to enter the country takes a job that otherwise would have to be filled by an American contract (temporary) engineer. They do so at a vastly reduced salary. It does not matter whether the individual is imported directly from overseas or through our university system.

The foreign worker is used by industry as the leveling mechanism for supply and demand. If demand looks as if it will exceed their concept of supply, then they have the ability to feed in a few thousand foreign workers to bring that ratio back into line. They are able to control salaries with this mechanism.

The truth of these statements are reflected in the salary levels that do not keep pace with the level of inflation. If the salaries had not kept pace for a single year, that would be one matter, but the engineer has not kept pace since at least the base year for the CPI of 1967!

EDUCATION

No one questions the need for a highly educated technical workforce. It is imperative that this nation maintain it's technological leadership both from an economic and defense perspective. It is the belief of the American Engineering Association that this leadership must be maintained with citizens of the United States.

Academia would have us believe that the worlds "best and brightest" are all from somewhere else. Early in 1983, academia was before Congress for funds "to solve the crisis in engineering" and testified before Congress that they must have access to the worlds best and brightest regardless of the country of origin. During that period of time they requested funds to enlarge the schools to produce more engineers, were turning away U.S. citizens from the schools because of the "overcrowded conditions" and at the same time were RECRUITING STUDENTS FROM OVERSEAS.

Their justification for the overseas recruiting was that the World War II baby boom had already passed through the schools and they were experiencing declining enrollments. The "hot fields" they were pushing overseas were of course engineering, mathematics, computer science and the natural sciences.

They neglected to tell anyone that there were already more foreign students in U.S. engineering schools than all of the U.S. minorities (excluding women) combined. They did not try to recruit this nations poor and underprivileged. I wonder how many George Washington Carver's have been overlooked because of these practices? The American taxpayer was being asked for billions of dollars to enlarge the schools merely to accomodate larger populations of foreign students.

One of their arguments used to justify the requests for funds was that Japan and Russia graduate several times the number of engineers each year that the U.S. does. They neglect to point out that West Germany who produces fewer engineers, on a population basis, that the United States does is one of the worlds leading technology based economies. The competitive edge is dependent not on the quantity of engineers produced but by the quality.

It is important, I think, to point out that our colleges and universities rely heavily on the financial support of industry. They receive grants and gifts of cash and equipment from industry. The least they can do is to provide a few thousand foreign engineers who are willing to work for less than their citizen counterparts. After all we need access to the worlds best and brightest. This aspect of the industrial-academic relationship deserves very close scrutiny.

GOVERNMENT ROLL

As one would expect, the actions of the federal government is perhaps the single largest factor affecting the engineering profession. There is a very important inter-relationship between the actions you take when when working on educational issues, immigration issues, the defense budget and a myriad of other issues and the health and wellbeing of the engineering and technical community.

For example any hint of a possible shortage of engineers that you find here will be reflected in more students entering engineering school and relaxed immigration laws for technical workers. An overproduction of engineers is gross disservice to both those graduates who will never work in his or her chosen profession and the taxpayer who funded the enlarged schools. Both of these items we feel are very detrimental to the engineering profession. Reaction to actions such as this can only result in more professionals leaving the field.

In addition, I would suggest that government find some way of reducing the cyclical nature of the profession. This is a very important factor in the decision of many individuals to leave the profession for other fields. Perhaps higher defense and space funding in years of economic downturns versus lower funding in years of plenty modified by actual needs, of course, would be a worthwhile pursuit.

No one will state that we can continue our defense buildup at the current record levels of spending indefinitely. The higher the peaks, the lower the valleys when it comes time to pay the piper. Sharp, harsh reductions in the defense budget will only result in thousands of engineers and scientists being laid off as was the case in the early 1970's; only this time I believe it will be much worse. Even with the huge sums of defense funds, the electronics industry today is in the worst recession in the history of the industry.

Recent calls for a freeze in the salaries of all defense workers by some members of Congress will have very negative effects for attracting engineers into that industry. We agree that the one hundred to three hundred dollar an hour labor rates Congress sees are very high. You must realize, however, that the individual is receiving perhaps fifteen to twenty dollars an hour. In fact a recent GAO study indicated that engineers in the defense industry were making on the average 2.5% LESS THAN THEIR COUNTERPARTS IN OTHER INDUSTRIES. [REFERENCE #12]

It is not the salaries of the workers that needs to be frozen, but the markup over the salary and benefits that the contractor receives that needs to be cut. Many of the contractors will love the "freeze the salaries" requests because of the multi-year procurement policies. They already have built-in salary increases which the contractors will refuse to pass along to the workers. That can only translate to larger profits for the contractors and fewer engineers with less experience and lower quality.

One practice of the federal government, which if not illegal is certainly unethical is the participation of the Los Alamos and Lawrence Livermore National Laboratories in the salary cartel know as the "R&D Group". Topics of conversation they admitted to included "SALARY-REDUCTION-PLANS" and "DISCUSSIONS OF THE EFFECTS OF THE SIMPSON-MAZZOLI IMMIGRATION BILL". "The discussion centered on the recruitment of technical employees who are aliens." They denied they discussed "future salaries" but one GE official stated that **"WE SWAP SALARY DATA WITH ABOUT 30 OTHER COMPANIES....FROM THIS DATA, WE DETERMINE WHERE WE ARE AND WHERE WE WANT TO GO."** [REFERENCE #13] In addition to the federal labs, many of the members of this cartel are members of the American Electronic Association. Can practices such as this have a positive effect on any "shortage profession"?

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Table 3. Engineering Degrees by Curriculum, 1983.

	Bachelor's	*Master's*	*Engr.*	*Doctor*
Aerospace	2,207	496	16	97
Agricultural	704	146		51
Architectural	508	30		—
Biomedical	677	178		80
Ceramic	294	55		19
Chemical	7,499	1,500	9	379
Civil	10,484	3,285	32	280
Computer	2,843	1,419	1	102
Electrical & Electron.	18,590	4,845	85	629
Engrg. Science	1,298	408		170
Environmental	292	456		86
Engrg. General	1,823	489	1	78
Industrial & Manuf.	3,906	1,400	10	108
Marine, Nav. Arch.	699	144	19	18
Mechanical	16,484	2,984	37	389
Mining & Mineral	1,019	250		84
Mat'ls & Metall.	1,086	561	2	229
Nuclear	420	301	10	114
Petroleum	1,420	225	2	14
Systems	210	418	12	96
Other	247	93		3
Total	72,471	19,673	236	3,023

Table 2. Engineering Enrollment, Fall 1983, by Curriculum.

	Undergraduate Students							Graduate Students				
	Full-Time					All	Total	Full-Time			All	All
	1st Year	2nd Year	3rd Year	4th Year	5th Year	Full-Time	Part-Time	Ms. Deg.	Engr. Deg.	Doc. Deg.	Full-Time	Part-Time
Aerospace	4,006	3,551	3,161	3,282	116	14,116	868	1,180	16	608	1,804	570
Agricultural	517	647	741	1,041	49	2,995	52	426	9	247	682	100
Architectural	625	504	481	544	223	2,377	152	111	—	3	114	24
Bioengineering	1,011	979	891	863	3	3,747	96	679	—	300	979	263
Ceramic	167	211	320	332	4	1,034	38	134	1	113	248	63
Chemical	8,579	7,244	8,266	10,446	680	33,215	1,855	3,378	272	2,458	6,108	1,563
Civil	7,109	7,565	9,384	13,927	882	38,867	3,567	5,540	129	2,019	7,688	3,671
Computer	6,798	5,248	4,957	4,970	461	22,424	1,897	2,768	24	976	3,768	4,342
Electrical	23,901	23,923	26,140	30,264	1,812	106,240	12,586	8,906	196	4,142	13,243	9,623
Eng. Science	1,277	1,284	1,558	1,769	65	5,953	844	824	41	1,045	1,910	825
Environmental	82	128	283	433	32	956	45	699	33	246	978	471
General	32,842	13,847	4,876	4,190	357	56,112	3,808	1,330	7	395	1,732	2,613
Industrial	1,863	2,750	3,960	5,192	378	14,153	1,073	2,077	41	660	2,778	1,948
Marine	507	695	776	868	1	2,847	41	519	76	118	712	102
Matls. & Metall.	807	756	880	1,432	103	3,777	186	1,137	25	1,233	2,395	582
Mechanical	12,754	14,725	19,103	23,498	1,379	71,459	7,245	5,883	132	2,826	8,621	4,808
Mining	702	828	952	1,509	13	4,004	137	347	7	340	694	277
Nuclear	440	478	561	550	42	2,071	65	590	13	447	1,050	213
Other	183	187	285	453	7	1,115	106	173	—	13	186	377
Petroleum	1,361	1,861	1,838	2,608	20	7,408	190	538	4	83	625	455
Pre-Engineering	5,874	1,955	820	215	80	8,944	233	—	—	—	—	—
Systems	523	632	632	650	6	2,443	279	550	34	267	851	985
Total	109,830	88,516	91,233	108,636	6,722	406,144	36,061	37,709	1,087	18,540	57,238	33,674
Curricula Accredited by ABET	59,259	63,553	74,779	92,735	5,618	295,944	27,180	26,789	864	12,290	39,943	19,999

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ance that the people did the numbers right, since they came out the same in all three cases. More importantly, because the common methodology of these studies makes a good deal of sense, we have some reason for confidence in them. On the other hand, the American Electronics Association study, which is something of an outlier, does have some important methodological weaknesses that were identified in the discussion and commentary at the symposium. There is, I think, therefore good reason to discount those results.

On the supply side there is also a large measure of agreement. In that case, the consensus is that we have very limited knowledge about the supply of engineers. The NSF people have, conceptually, the most illuminating approach and the one with the most promise for solid future results; but their staff are frank to acknowledge that the empirical quality of what they have so far been able to do on the supply side is not terribly good and that a lot more work needs to be done. We don't have a sufficiently good understanding even of the "new entrants" part of the picture, of how undergraduates make their decisions about whether to go to college or what to major in. The National Center on Education Statistics' projections that NSF relies on are really very mechanical and don't have any behavioral decision-making in them and, therefore, are not too reliable. But our understanding of that part of the supply of engineers who are "in-mobile" from other fields is even less adequate. As several participants noted, we don't even have clear information about where people are coming from, where they are going, and in what ways mobile people are different from in-mobile ones. We certainly have even less in the way of a good economic and social understanding of what underlies those movements and how to explain and predict them. A lot of important work remains to be done there. The agreement on the supply side, then, is that this work needs to be done.

Both the presentations and discussions thus point to the conclusion that we are confronted not so much with disagreement, but rather with agreement on some very important limitations on what we know. I think that's real progress. This was, as these things go, a rather well focused symposium, and I think substantial concensus emerged on what we need to know more about.

Now the question is "Where does all that agreement lead us in terms of how we should interpret it and where we should go next?" One place it leads us is to Jerry Had-

MDAC-STL FACT SHEET

(FEBRUARY 6, 1984)

ADVANCED TECHNOLOGY

o Score Card for 1983 CRAD Wins--During calendar year 1983, we won 68 awards worth $55.5 million for CRAD work, achieving a win/loss ratio of .89. These figures make 1983 a good year for our CRAD program. CRAD is Contract Research and Development, as distinguished from both Independent Research and Development (IRAD) and production contracts.

LASER COMMUNICATIONS

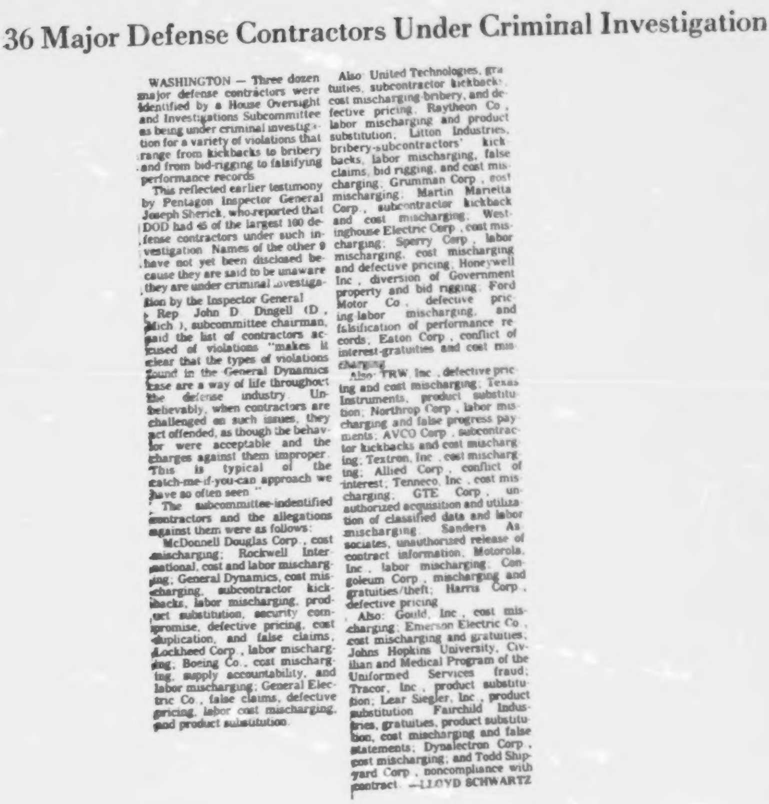
o New Contract with NASA (Goddard Space Flight Center)--We negotiated a $100,000 contract with NASA for part of the work on the Laser Intersatellite Link Experiment that could fly on NASA's Advanced Communication Technology satellite in 1988. This contract is for the conceptual design of the Lasercom transmitter/receiver and will hopefully lead to follow-on contracts to build the flight hardware. The Laser Link Experiment will demonstrate laser communications among three locations--a terminal on Earth, a transmitter/receiver in the payload bay of the Space Shuttle, and a satellite in geosynchronous orbit (flying at an altitude of 22,300 nautical miles, the satellite makes one revolution of the Earth every 24 hours). The purpose of the experiment is to demonstrate the suitability of lasers for transmitting data at very high rates among satellites. If successful, laser communication links could be used for future NASA, Space Shuttle, and commercial applications.

o Breakthrough in Laser Technology--On January 12th, MDAC-STL achieved the world's first successful operation of a slab laser pumped by an area array of diodes. Many bars, each of which contained tens of diodes, were stacked together to form the array. The light output of the two-dimensional array was coupled directly into the top surface of the slab of laser material. The diode-pumped slab laser has the advantage of higher output power than can be achieved with diode-pumped rod lasers and is more efficient than conventional flashlamp-pumped slab lasers.

o New Commercial Order for Opto-Electronics Center (OEC)--Our new Opto-Electronics Center in Elmsford, New York received its first commercial order for high quality fiber-optic TV links, a product that may become one of OEC's leading commercial items. This was an initial order for 25 fiber-optic TV links and is worth about $200,000. The main thrust of OEC, which we acquired in September 1983, will be to support the work of MDC components in various laser diode and fiber-optic areas, but it will also sell products like fiber-optic TV links to government and commercial customers.

PERSONNEL

o Results of 1982-83 College Recruiting--During this period we considered 4039 applicants to fill 183 positions. We made offers to 388 of these people and 130 of them accepted. This means that we filled 71% of our openings and that we had an acceptance rate of 34%, which is very good by industry standards.



36 Major Defense Contractors Under Criminal Investigation

WASHINGTON — Three dozen major defense contractors were identified by a House Oversight and Investigations Subcommittee as being under criminal investigation for a variety of violations that range from kickbacks to bribery and from bid-rigging to falsifying performance records

This reflected earlier testimony by Pentagon Inspector General Joseph Sherick, who reported that DOD had 45 of the largest 100 defense contractors under such investigation Names of the other 9 have not yet been disclosed because they are said to be unaware they are under criminal investigation by the Inspector General

Rep John D Dingell (D, Mich), subcommittee chairman, said the list of contractors accused of violations "makes it clear that the types of violations found in the General Dynamics case are a way of life throughout the defense industry. Unbelievably, when contractors are challenged on such issues, they act offended, as though the behavior were acceptable and the charges against them improper. This is typical of the catch-me-if-you-can approach we have so often seen "

The subcommittee-indentified contractors and the allegations against them were as follows:

McDonnell Douglas Corp , cost mischarging; Rockwell International, cost and labor mischarging; General Dynamics, cost mischarging, subcontractor kickbacks, labor mischarging, product substitution, security compromise, defective pricing, cost duplication, and false claims, Lockheed Corp , labor mischarging; Boeing Co , cost mischarging, supply accountability, and labor mischarging; General Electric Co , false claims, defective pricing, labor cost mischarging, and product substitution.

Also United Technologies, gratuities, subcontractor kickbacks, cost mischarging-bribery, and defective pricing, Raytheon Co , labor mischarging and product substitution, Litton Industries, bribery-subcontractors' kickbacks, labor mischarging, false claims, bid rigging, and cost mischarging, Grumman Corp , cost mischarging; Martin Marietta Corp , subcontractor kickback and cost mischarging; Westinghouse Electric Corp , cost mischarging; Sperry Corp , labor mischarging, cost mischarging and defective pricing, Honeywell Inc , diversion of Government property and bid rigging; Ford Motor Co , defective pricing labor mischarging, and falsification of performance records, Eaton Corp , conflict of interest-gratuities and cost mischarging

Also: TRW Inc , defective pricing and cost mischarging; Texas Instruments, product substitution; Northrop Corp , labor mischarging and false progress payments; AVCO Corp , subcontractor kickbacks and cost mischarging; Textron, Inc , cost mischarging; Allied Corp , conflict of interest; Tenneco, Inc , cost mischarging; GTE Corp , unauthorized acquisition and utilization of classified data and labor mischarging. Sanders Associates, unauthorized release of contract information, Motorola, Inc , labor mischarging; Congoleum Corp , mischarging and gratuities/theft; Harris Corp , defective pricing

Also: Gould, Inc , cost mischarging; Emerson Electric Co , cost mischarging and gratuities, Johns Hopkins University, Civilian and Medical Program of the Uniformed Services fraud; Tracor, Inc , product substitution; Lear Siegler, Inc , product substitution Fairchild Industries, gratuities, product substitution, cost mischarging and false statements; Dynalectron Corp , cost mischarging; and Todd Shipyard Corp , noncompliance with contract. —LLOYD SCHWARTZ

SECTION I INTRODUCTION

THE SOCIETY

The Institute of Electrical and Electronics Engineers, Inc. (IEEE) is a professional, technical society, transnational in scope with 235,000 members in 120 countries. Historically, one of its major purposes has been ". . . scientific and educational, directed toward the advancement of the theory and practice of electrical engineering, electronics, radio and the allied branches of engineering and the related arts and sciences." As of January 13, 1983, IEEE had 143,608 higher grade employed members in the U.S.

PURPOSE OF THE SURVEY

The purpose of the 1983 IEEE U.S. Salary and Fringe Benefit Survey was well stated in a letter accompanying each survey form mailed to the members:

> *The 1983 survey results will continue the development of data for long-term salary trends and benefits that have already been found so valuable by members of the electrical/electronics/computer engineering field in determining salary and compensation practices.*

CHARACTERISTICS OF RESPONDENTS

Other than income, relatively small changes have occurred in the majority of respondent characteristics since 1979 (as shown in Exhibit 1).

The average age of the IEEE salary survey respondents has decreased by more than two years since 1978. The average age of respondents listed in the 1979 survey (which covered the 1978 calendar year) was 43.1 years while in the 1983 survey it was 40.6. The increase in the percentage of younger members may have caused a depression of median salary reported in 1983.

Throughout this report, whenever the word "member" appears with a lower case initial letter, it refers to the entire group. If it appears with an initial capital letter, it refers to membership grade.

EXHIBIT 1. CHARACTERISTICS OF RESPONDENTS—1983, 1981 AND 1979

	1983 Survey	*1981 Survey*	*1979 Survey*
Income (of all respondents)	$40,000	$34,500	$29,901*
Years of Experience	17.0	17.7	* 17.7
Employed But Available for a Job Change to Area of Primary Technical Competence	4.6%	6.8%	7.1%
Unemployed Involuntarily	0.1%	0.5%	0.4%
Age (in years)	40.6	42.7	43.1
Years with Present Employer	9.9	11.2	11.9
Percent with Bachelors Degree (as highest degree)	47.6%	51.1%	50.5%
Percent Male	96.0%	98.5%	98.9%
Percent Caucasian	90.0%	94.1%	93.7%
Respective survey respondents were as follows:			
Members	5,855 (77.5%)	5,519 (82.3%)	6,255 (76.9%)
Senior Members	862 (11.4%)	864 (14.4%)	1,229 (15.1%)
Fellows	111 (1.5%)	115 (1.7%)	259 (3.2%)
Associates, No Response, or Inapplicable	726 (9.6%)	159 (2.4%)	36[illegible] (4.8%)
Total	7,554	6,757	8,131

*Working in area of primary technical competence

SECTION II HIGHLIGHTS

COMPENSATION

The median annual income of survey participants was $40,000 as of February 1, 1983. This represents an increase of 15.9% since the preceding survey, compared to an increase in the Consumer Price Index of 18.[illegible]% since that survey. Individual salaries varied widely from $27,000 at the first decile to $61,000 at the ninth decile. Since the 1979 survey, EEs' income have increased 33.8% whereas the Consumer Price Index has increased only slightly more than 49%. This represents about a 15.2% decrease in purchasing power.

Some 33% of all respondents reported income from commissions and bonuses, the median amount being $2,238.

Unemployment was extremely low, less than 0.1% of all respondents.

About one-quarter of the respondents reported supplemental income. The median category was $1,500 to $2,499.

Income showed a consistent but flattening increase with increased engineering experience. The median income of those working in their areas of primary technical competence increased from $27,114 for those with under two years of experience to $49,974 for those with 30 years of experience or more.

Income by highest degree earned was greatest for those with doctoral degrees, a median of $48,225. Lowest median income was $30,500 for those with B.E.T. degrees even though this category was not the "lowest" degree earned.

Concentrated geographic areas, rather than total region, seemed to show the highest income levels, as might be expected. Los Angeles/San Diego had a median income for all EEs of $46,700, followed by New York City ($46,100), and Washington/Baltimore ($45,200). Lowest median income was reported by Region 3 at $37,878.

Electronic Engineering Times - Monday, June 17, 1985

1985 • *Electronic Engineering Times*

ANNUAL SALARY SURVEY

Part 1

By Matthew J. Doherty

Engineering salaries did not keep up with or exceed the rate of inflation for the first time in three years, according to the 1985 *EE Times* Annual Salary Survey. The survey has been conducted since 1974.

The second part of the survey, which polled engineers on their career concerns and other issues, will be published on June 24.

The mean (average) salary in 1985 for all respondents to the survey was $43,000, an increase of 3.2 percent over last year's $41,662.

That modest gain was offset by a rise in the Consumer Price Index of 3.7 percent since April 1984, meaning that the purchasing power of engineers failed to keep up with rising prices. That compares unfavorably to 1984, when salaries increased a remarkable 16.4 percent over the previous year.

Of course, 1984 was a good year for high technology. As everyone knows, the picture this year has not been as rosy, as plant shutdowns, salary freezes and layoffs have affected some engineering salaries.

Aviation Week & Space Technology, July 2, 1984

Farther north at Boeing Aerospace Co.'s Seattle, Wash., plant, the Defense Contract Audit Agency has complained to Boeing's director of finance, G. L. Jorgensen, that the company's engineering work force is engaged in nonproductive activities 39.4% of the time when the aerospace industry standard relaxation allowance is only 10%. The agency claims Boeing could save more than $54.5 million a year by taking management actions to reduce the level to 10%. Boeing has denied access to records. The agency wants Boeing to establish a formal work measurement system and make immediate improvements in what the agency claims is insufficient supervisory control. Boeing's response was huffy, to say the least: "Management of the Boeing engineering team has evolved beyond the point where time and motion studies, which the company discarded years ago, are considered useful in determining engineering productivity." And engineer skills, said Boeing, have been proved in the marketplace, anyhow.

MACHINE DESIGN

MAY 26, 1983

Faulty practices stymie engineers

Engineer productivity sags due to shoddy work, reward systems.

For optimum utilization of technical manpower, the ratio of support personnel to engineers should be 4:1, contends the engineering utilization committee of the American Association of Engineering Societies, New York. However, the committee has found that the ratio is less than 1:1 throughout industry.

Adequate staff support is considered essential to free engineers from routine matters and to give them work that challenges their capabilities. Nonetheless, industry persists in limiting work assignments and distorting the hierarchy of the engineering team. Evidence of this fact is borne out in the ratios of engineering technicians to engineers in five industries: 0.24:1 in guided missiles and space vehicles, 0.39:1 in aircraft and parts, 0.51:1 in communication equipment, 0.94:1 in measuring and control instruments, and 0.94:1 in office and computer machinery.

"Salary compression is another major symptom of poor engineering utilization," reports the AAES committee. "Starting salaries offered to attract new graduates increase each year while engineers in midcareer typically are not compensated proportionally to their contribution to the organization."

Electronic Engineering Times - Monday, April 11, 1983

Study Says That Many Graduates In Engineering Are Dissatisfied

STONY BROOK, NY — About 32.7 percent of all students who entered college in 1970 and graduated in engineering disciplines consider themselves underemployed, according to a recent survey.

Some kinds of engineers are more dissatisfied than others. Fifty percent of aeronautical engineers who entered engineering 13 years ago say they are underemployed; running a close second are industrial engineers at 47.1 percent. For those who were electrical engineering majors in college, the figures are dramatically lower: Only 28.6 percent see themselves as underemployed.

The study, "Underemployment Among College Graduates," was authored by Jo and Thomas Phelan of the Research Group for Human Development and Educational Policy and department of sociology at the State University of New York at Stony Brook.

The primary data source for the study was a national sample of 9039 students in many different fields—not just engineering—attending hundreds of colleges across the U.S. in 1970. The study was limited to those who had received a bachelor's degree only.

According to the Phelans, two vital aspects of underemployment among the grads were examined: actual causes of underemployment, and occupations in which the phenomenon occurs most dramatically. The study points to a national problem, the researchers say: while higher education has expanded dramatically in the U.S., the pool of jobs using skills acquired in college has not. Underemployment, they say, has become a national problem.

The Phelans used two measures in producing their statistics: the respondent's own assessment as to underemployment, and the difference between the respondent's years of education and the General Educational Development (GED) required by the occupation. In addition, multivariate statistics such as path analysis and analysis of covariance was used to analyze the relationship between underemployment and variables like background, attitudes and behaviors, and college characteristics such as selectivity.

Gender differences were also noted, the Phelans say. Although women tend to earn substantially less than men in the early stages of a career, they are generally less underemployed. Also, the figures show a decline in the arts and humanities, the social sciences, education and mathematics, and an increase in the percentage of students intending to become engineers or business majors.

The trends "suggest that college students in the seventies were attempting to adjust to the job market by choosing majors they hoped would lead to better jobs. Ironically, to the extent that their aim was to find a job which would utilize their education, many of those students may have been making the wrong choices."

Underemployment figures for engineering disciplines according to the study are:

- Aeronautical engineering—50 percent.
- Civil engineering—31.4 percent.
- Chemical engineering—21.2 percent.
- Industrial engineering—47.1 percent.
- Mechanical engineering—36.4 percent.
- Electrical engineering—28.6 percent.
- Other engineering disciplines—26.3 percent.

Employment, 1978	3,700
Projected employment, 1990	4,700
Percent growth, 1978–90	27.0
Average annual openings, 1978–90	200
Growth	100
Replacement	100

Available training data:

Degrees in range management:	1977–78
Bachelor's degrees	221
Master's degrees	100
Doctor's degrees	27

Soil conservationists. Most soil conservationists have degrees in agronomy or a closely related field of natural resource science, such as wildlife biology, forestry, or range management. Only a few colleges and universities offer degrees in soil conservation. A background in agricultural engineering and courses in cartography are very useful. The ability to communicate clearly, both orally and in writing, also is important.

Employment, 1978	9,300
Projected employment, 1990	11,400
Percent growth, 1978–90	21.7
Average annual openings, 1978–90	450
Growth	200
Replacement	250

Available training data:

Degrees in agronomy:	1977–78
Bachelor's degrees	1,609
Master's degrees	443
Doctor's degrees	157

Engineers

A bachelor's degree in engineering is required for most entry positions. College graduates who have degrees in one of the natural sciences or mathematics also may qualify for some beginning jobs. Occasionally, experienced technicians are able to advance to some engineering jobs. Graduate training in engineering is being emphasized for a number of jobs, and is essential for teaching and research, and for advancement in many areas.

In all States, engineers must be registered if they offer their services directly to the public, or if they design buildings, dams, or other projects where safety is a factor. Registration requirements include a degree from an accredited engineering school, 4 years of relevant work experience, and passing a State-board written examination. The majority of engineers are not registered.

Employment opportunities for those with engineering degrees are expected to be good through the 1980's. Growth and replacement needs resulting from deaths and retirements are expected to result in an annual average of about 46,500 openings between 1978 and 1990. In addition, many openings will occur each year as employed engineers transfer to other occupations, but the number is difficult to estimate. The major source of supply of engineers is new graduates majoring in engineering. The National Center for Education Statistics projects that about 81,400 bachelor's degrees in engineering will be awarded annually during this period. Followup on college graduates of the 1960's indicate that about 85 percent of the bachelor's degree recipients in engineering, including those who went on to graduate study, actually entered the field. This proportion dropped to 80 percent for graduates during the mid-1970's. Because of the high level of recruiting during this period, this entry rate probably represents fairly accurately the proportion of graduates who seek engineering jobs. If an 80-percent rate continues, an average of about 65,000 are expected to enter the field annually. Other sources of supply are recent graduates in other fields—primarily mathematics and the natural sciences—immigrants, reentrants to the labor force, and transfers from other occupations. The projected large increase in engineering degrees may result in more limited opportunities than in the past for entrants from these sources, however.

Employment, 1978	1,136,000
Projected employment, 1990	1,441,000
Percent growth, 1978–90	26.8
Average annual openings, 1978–90	46,500
Growth	25,500
Replacement[1]	21,000

Available training data:	1977–78	Projected 1978–90 (annual average)
Degrees in engineering:[2]		
Bachelor's degrees	56,009	81,441
Master's degrees	16,409	16,722
Doctor's degrees	2,440	3,158

[1] Does not include openings resulting from transfers.

[2] Includes engineering technology.

Environmental scientists

Geologists. A bachelor's degree in geology or a related field is appropriate training for many entry jobs. An advanced degree is helpful for promotion in most types of work and is required for college teaching and some research positions.

Employment opportunities in geology are expected to be good for geology and earth science graduates. Growth in the employment of geologists and replacement needs are expected to result in about 1,700 openings each year between 1978 and 1990. The major source of supply of geologists is new graduates majoring in geology and earth sciences. The National Center for Education Statistics projects that bachelor's degrees in these majors will average about 5,400 during this

NSF Director Bloch Is 'Unconvinced' About Engineering Shortages

But Former IBM Executive Tells American Society For Engineering Education That Faculty Vacancies Are Real

By Matthew J. Doherty

ATLANTA — The director of the National Science Foundation (NSF) said recently that he doubted projections of an engineering shortage.

NSF director Erich Bloch told members of the American Society of Engineering Education, who met here June 16-20, that he does believe there is not enough engineering faculty. But he added, "I am less convinced of the advertised engineering shortage in general."

During the past year, the American Electronics Association has asserted that there is a shortage of both engineering faculty and engineers.

Bloch told *EE Times* after his speech that there is not a "chronic shortage" of engineers. There may be some temporary shortages, but they are self-correcting, he said. "The system is robust."

Echoing the findings of a recent National Research Council study on engineering education, Bloch urged universities to take steps to make faculty positions more attractive. He cited faculty-vacancy figures ranging from a low of 1,600 to a high of 6,000 nationwide.

He blamed the lack of "sufficiently qualified faculty" for a drop-off in the number of engineering schools rating six-year accreditation from ABET (Accreditation Board for Engineering and Technology) this year. According to Bloch, only 40 percent of engineering schools examined by ABET were granted six-year accreditation, compared to 59 percent in 1979.

Other Problems

Other problems confronting academia, Bloch said, are aging laboratory equipment and "a lack of understanding of the need for engineering design in curricula."

Erich Bloch: Engineering shortages are not "chronic."

The former IBM Corp. executive called upon universities to develop more links to industry, particularly in getting it to sponsor research.

He also criticized universities for "not changing quickly enough" in responding to the need for more cross-disciplinary research. Such research, he noted, is needed if the United States expects to compete with Japan and other countries in developing basic research.

Bloch acknowledged that encouraging research across disciplinary boundaries "runs counter to university structures." But he said that science, engineering and technology must be seen as a whole system, not as separate disciplines. Discoveries in one area drive advances in another, he noted.

Bloch pointed to the NSF's Engineering Research Center program as an example of the federal government's commitment to encouraging cross-disciplinary research.

U.S. Faces A Challenge

Sounding much like a political candidate on the stump, Bloch said the United States is "facing a vigorous economic challenge from other countries," including Japan, Taiwan, Korea, Malaysia and Hong Kong. There has been a sharp increase in competition and research, he said. "I don't think we realize that as much as we should."

Urges Involvement

Bloch urged the engineering community to become more involved with the various NSF advisory committees. And he also told *EE Times* that he is opposed to continuing legislative efforts in Congress to change the name of the NSF to the National Science and Engineering Foundation. The National Society of Professional Engineers supports such a proposal.

Bloch offered his views during a plenary session of the ASEE conference on June 18. The theme of this year's conference, which attracted several hundred participants, was computer-aided engineering (CAE).

FORT WORTH STAR-TELEGRAM ■ SUNDAY, OCTOBER 28, 1984

Defense firms pay execs more

By MARK THOMPSON
Star-Telegram Washington Bureau

WASHINGTON — Executives at General Dynamics Fort Worth Division and 11 other defense firms take home paychecks and bonuses averaging 42 percent more than those earned by executives at similar but non-defense companies, the government said in a report released Saturday.

That contrasts sharply with the pay received by engineers and other professionals at the 12 aerospace firms, which lags 2.5 percent behind the salaries paid their counterparts in non-defense companies, the General Accounting Office reported.

Factory workers at the defense firms earned 8 percent more than workers employed in the production of civilian durable goods, while clerical employees of the defense companies received 9 percent more pay than their civilian counterparts, the study found.

Fringe benefits at the defense firms also were found to be better than those available elsewhere in industry.

The detailed GAO report, based on 1982 data, was released by Rep. Jack Brooks, D-Beaumont, chairman of the House Government Operations Committee.

In a letter sent Friday to Secretary of Defense Caspar W. Weinberger, and in comments accompanying the GAO report, Brooks protested the size of the salaries paid and the fringe benefits provided the aerospace firms' top executives.

"Since the taxpayers pay the bill, the compensation for defense contractors' executives ought to be reasonable," Brooks said. "It is just as outrageous to allow reimbursement for these salaries as it is for the Department of Defense to pay unconscionable prices for spare parts.

"The review reveals that not only did the executives of these firms receive the pay differential cited, but they also received non-cash perquisites, including stock options, the use of automobiles, social club memberships, and free travel for spouses."

Brooks told Weinberger that since the 12 firms derive most of their revenues from the Pentagon, the military should scrutinize the salaries being paid and try to bring them more into line with the averages cited by the GAO.

"Because compensation is the largest single element in defense contracts, it is vitally important that the problems raised in this study be addressed if we are ever going to control defense costs," Brooks told the defense chief. Payroll accounts for roughly 70 percent of Air Force contract costs.

The Pentagon had no immediate comment on the study.

In addition to General Dynamics' Fort Worth operation, the GAO surveyed compensation at the LTV Aerospace and Defense Co. of Dallas.

Among the 10 other firms reviewed were the Boeing Military Airplane Co., the Grumman Aerospace Corp., Hughes Helicopters Inc., the McDonnell Aircraft Corp., the Northrop Corp., and Sikorsky Aircraft.

The pay scales from all the firms were lumped together and averaged so that figures for individual companies could not be determined.

While Pentagon regulations require pay levels for contractors' employees to be "reasonable," that term never has been defined, the GAO said.

"We were unable to reach a conclusion on the reasonableness of compensation paid by the 12 contractors," the agency said.

The GAO compared the salaries at the defense firms with surveys done by the American Management Association and the Department of Labor's Bureau of Labor Statistics.

The GAO also reported that salaries paid by the defense contractors between 1978 and 1983 rose faster than the cost of living and faster than the salaries received by non-defense industry workers.

Using 1978 as the base year at 100 percent, the GAO said the cost of living had risen to 153 percent by 1982, while the average cost of labor had risen to 146 percent. At the 12 defense firms surveyed, salaries rose from 100 percent in 1978 to 175 percent in 1982.

The congressional watchdog agency found a wide range in the salaries and bonuses paid to six top officials in the defense firms.

The average remuneration paid to the firms' chief executive officer was $285,494, or 51 percent more than that received by executives running non-defense firms. The actual salaries paid the top officials of the defense firms ranged from 2 percent to 109 percent more than the non-defense average of $189,316.

Senior financial, engineering and manufacturing executives in the aerospace firms also earned much more than their civilian counterparts, while marketing and personnel executives at the defense firms pocketed only slightly more than their non-defense colleagues.

Taken together, those top six officials were paid an average of 42 percent more than their civilian peers.

The aerospace executives received annual bonuses averaging 82 percent of their base salaries, compared with the average 29 percent bonus in the American Management Association survey.

"Comparisons are not conclusions," the GAO stressed, adding, "10 percent more does not mean 10 percent too much."

The agency noted that the aerospace firms it surveyed were large — which tends to boost salaries — and that some executives at defense firms may do more than their civilian counterparts.

The availability of fringe benefits was greater at the defense firms than in others, the study said.

Health insurance without charge to the employees was available to 93 percent of the defense workers, compared to 71 percent of the non-defense workers, the GAO said.

The agency said it approved of recent Pentagon efforts to determine what constitutes a "reasonable" salary.

"We believe the fundamental solution rests with developing criteria which are viewed as acceptable and fair both to the Defense Department and the contractors and usable and enforceable by those charged with overseeing compensation reasonableness," the report concluded.

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Electronic Engineering Times - Monday, October 8, 1984

29 Firms, Labs Quietly Swap Salary Data In R&D Group

By Matthew J. Doherty

A syndicate of 29 major corporations, universities and government labs, unofficially known as the "R&D Group," annually meets in secret to trade confidential information on salaries and other personnel matters, including pensions, benefit plans, salary-reduction plans and policies on patents.

Because the syndicate includes some of the electronics industry's largest technology companies—including AT&T Co. and General Electric Co.—and encompasses virtually all of the major technology pacesetters, the R&D Group appears to have a significant and unprecedented role in determining the industry's working environment.

So far, the R&D Group has escaped government scrutiny, perhaps because the federal government is a participant. Meanwhile, corporate lawyers, including activists in the American Bar Association, disagree on whether the syndicate, by agreeing to exchange current salary data, violates antitrust law.

The group's members are a veritable Who's Who in research and development:

- Corporate members are: AT&T Bell Laboratories Inc., Communication Satellite Corp., the Calspan division of Arvin Industries Inc., the Charles Stark Draper Laboratory Inc., E.I. DuPont de Nemours & Co., Eastman Kodak Co., Exxon Corp., Ford Motor Co., GE, General Motors Corp., Hewlett-Packard Co., IBM Corp., Arthur D. Little Inc., Lockheed Corp., Rand Corp., RCA Laboratories, Sandia National Laboratories, Shell Oil Co., TRW Inc., Union Carbide Corp., Union Oil Co., Westinghouse Electric Corp. and Xerox Corp.
- University members include University of California at Berkeley, Johns Hopkins University, the Massachusetts Institute of Technology and
- Government laboratories include the Los Alamos National Laboratory and Lawrence Livermore National Laboratory.

According to sources, the R&D Group's primary purpose is to swap data on the salaries paid to employees in the members' research and development laboratories. The group looks at salaries paid by degree grouping and in the categories of supervisors and non-supervisors.

After the data have been submitted, the sources said, they are analyzed and combined into a comprehensive salary survey used only by the member companies and laboratories.

The group holds an annual meeting to discuss the information that has been put together and any questions regarding it, before the data are compiled and published. In addition, those at the meeting consider issues related to compensation. The 1984 meeting was held last month in Seattle, Wash., and included a discussion of the effects of the Simpson-Mazzoli Immigration Reform Act, according to one source who attended.

The discussion centered on the recruitment of technical employees who are aliens. Many of the companies that are part of the R&D group rely heavily on alien engineers.

Who Has Data Access?

Phillip Areeda, Langdell professor of law at Harvard University Law School, said the R&D Group raises a number of legal issues, which are all "complicated with data exchange."

Areeda has served as a special adviser to Presidents Dwight D. Eisenhower and Richard M. Nixon, and is known for his antitrust research. He suggested that the exchange of information on closed transactions should be viewed in terms of how it is used and whether other interested parties, such as the public or labor unions, have access to it.

Lawyers agree that the main criterion is whether the syndicate discusses future salaries or uses the information to set future wage levels.

One lawyer described the group as possibly being a "buyer's conspiracy," but another said the group's swapping of data, while uncommon, is probably not illegal in the eyes of the government.

No Comment From Justice

A Justice Department spokesman in the antitrust division had no comment on the R&D Group.

He suggested, however, that a number of factors would determine whether such a group violates antitrust law. Those factors would include the purpose of the information exchange, what its effect was and whether or not the data are made public or offered to the employees.

In recent interviews, several corporate delegates to the informal cartel discussed their practices and their longstanding custom of swapping salary data. However, they denied that the R&D Group discusses future salary levels.

A New York antitrust lawyer, who is prominent in bar-association activities but who requested anonymity, agreed. "Since they are not talking about the future, it's not likely to interest the Justice Department," he said.

Silent On Syndicate

Corporate members were not eager to volunteer much information about the syndicate. As one executive put it, "I do not think it would be proper for me to tell you who participates."

The group is not open to all companies with R&D labs, noted Alvin Bernstein, manager, employee relation operations, for GE Corporate Research and Development. It is available only to those companies that have successfully petitioned to join. A three-member council conducts an initial screening and then membership is determined by the entire body.

"We swap salary data with about 30 other employers," said Bernstein. "From this data, we determine where we stand and where we want to go."

He said that GE is interested in knowing where it stands "relative to the people who compete with us for manpower."

Sol Buchsbaum, executive vice president of Bell Labs, explained, "We like to compare apples to apples."

He said the data provide a "snapshot picture" of the prior year's salary levels among companies with comparable R&D organizations.

Buchsbaum added that the data enable group members to see whether they are "staying in step" or "falling behind" in

Who Attends

Delegates to the meeting are generally compensation professionals or personnel managers.

Bernstein explained why GE is a member of the R&D group: "The motive is that we don't want to be outbid." The best sources on current salaries are other companies, he said.

Annually, Bernstein continued, the syndicate members submit salary levels "as of a particular past date." That information is then analyzed statistically and compiled in a report which is disseminated to the members.

The report is intended to be a sampling of major top-quality R&D labs, said Kerry Wilson, manager of compensation at MIT, adding, "It gives you some idea of what the market is doing." He confirmed that the group performs an annual salary exchange, but called the practice a "fairly common one."

Wilson said the exchange of data is the type "you'd see characterized in dozens of surveys."

Bernstein, Buchsbaum and Wilson refuted allegations by a former GE employee that the group is "colluding" to set salary levels.

The former GE employee, who requested anonymity, described the group as a "salary cartel" that effectively sets engineering salaries. The ex-employee said the salary information is swapped and then used by the companies to determine salary curves for the future.

Salary Curved Used

The source recalled an Oct. 11, 1983 meeting, during which Bernstein presented a salary curve showing recommended raises in relation to salary and years of experience. The curve in question was being used to project 1984 salary increases, the source said, and was based on data gathered by the R&D Group.

Bernstein acknowledged the company's use of salary curves but called the charges of a salary cartel "absolutely false."

He called the former employee's memory of the meeting faulty and said the notion that the R&D Group is a cartel is "ridiculous."

"Anyone who believes there is some kind of collusion in controlling engineers' salaries has never seen the data," Bernstein said. He noted that the survey results show a very widespread range of salaries paid to people of comparable training.

AT&T Bell Laboratories Inc.
Communication Satellite Corp.
Calspan, division of Arvin Industries Inc.
Charles Stark Draper Laboratory Inc.
E.I. DuPont de Nemours & Co.
Eastman Kodak Co.
Exxon Corp.
Ford Motor Co.
General Electric Co.
General Motors Corp.
Hewlett-Packard Co.
IBM Corp.
Arthur D. Little Inc.
Lockheed Corp.
Rand Corp.
RCA Laboratories
Sandia National Laboratory
Shell Oil Co.
TRW Inc.
Union Carbide Corp.
Union Oil Co.
Westinghouse Electric Corp.
Xerox Corp.
University of California at Berkeley
Johns Hopkins University
Massachusetts Institute of Technology
Stanford University
Los Alamos National Laboratory
Lawrence Livermore National Laboratory

R&D GROUP

"We certainly do not get together to discuss what salaries should be," he explained. "To do so would possibly be illegal. We assiduously avoid talking about future salary levels."

Bernstein said salary increases at GE reflect an employee's performance and current salary rate. He acknowledged that the company grants a larger-percentage salary increase to highly ranked performers with less experience than it does to employees with more experience because they are already making more money.

"In the case of two performances of equal level, the one who is making more than the other will get a smaller increase," Bernstein explained. He added that the rate of change is "much more rapid" at the lower end, because the individual with less experience is learning more rapidly.

Past Vs. Future Salaries

Wilson described the survey as being open and "totally above board." He echoed Bernstein's statements on the possibility that future plans and salaries might be brought up among group members. "We talk only about what has happened, not what is going to happen," he declared.

Steve Yabroff, acting manager of the compensation division at Lawrence Livermore National Laboratory, also defended the group and its sharing of salary data.

He said the data gathered by the group are used by the participants "to assess the dynamics of the marketplace." Prospective plans are never discussed by anybody, added Yabroff, who attended the Seattle meeting.

"If that ever happened, a whole bunch of us would get up and leave the room," he said.

Yabroff said the salary data gathered by the R&D Group is more reliable than most other surveys because it involves a stable group of participants. He said the group's membership has been about the same for years, enabling the group to plot past trends more accurately.

"It measures our market better than other surveys we have seen," Yabroff remarked.

EE Times was unable to obtain copies of the R&D Group's salary survey because it is considered "confidential."

According to GE's Bernstein, there were originally about 20 members of the R&D Group. The group was first founded by MIT and was often referred to as the "MIT Salary Survey Group." Some companies dropped out over the years, he said, but they have been replaced by others.

The R&D Group has existed since the 1950s, sources said. The latest corporation to join the group is the Hewlett-Packard Co.

The group's existence is apparently known to few employees in the participating companies and is not generally known to companies outside of the group. When first contacted by *EE Times*, it was evident that the spokespersons at IBM and Hewlett-Packard were not familiar with the group or who represents them at the meetings.

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Mr. **Walgren**. Thank you very much, Mr. Reed. We appreciate that.

Dr. Rahn?

[A biographical sketch of Dr. Rahn follows:]

DR. RONALD OTTO RAHN

Born: 7 February, 1935.

Married: Sandra Weston Welton (1963).

Children: Karyn (1965) and Elizabeth (1967).

Education. 1953-1957: University of Connecticut—B.A. (Chemistry); 1957-1958: Iowa State College (Chemistry); 1958-1959: Boston University (Fine Arts); 1959-1963: Brandeis University—Ph.D. (Chemistry).

Positions: 1963-1965: Bell Telephone Laboratories—Postdoctoral Staff Fellow (Biophysics); 1965-present: Biology Division, Oak Ridge National Laboratory; 1972-present: Full Professor (part time), Univ. of Tenn. Biomedical School; 1979-present: Adjunct Professor (Physics), Clemson University; 1983-1984: Congressional Fellow (AAAS), Science and Technology Committee, U.S. House of Representatives; 1984-present: Laboratory of Molecular Pharmacology, National Cancer Institute, National Institutes of Health, Bethesda.

Societies: American Chemical Society; American Association for the Advancement of Science; American Society for Photobiology (Council, 1980-1983 and Representative to the American Institute of Biological Sciences, 1982—); Biophysical Society; Radiation Research Society.

Teaching: DNA Chemistry, Quantum Chemistry, Biophysics, Biological Applications of Electron Spin Resonance.

Research: Photochemistry and luminescence of proteins and nucleic acids, Electron spin resonance, Binding of metal ions and small molecules to DNA, Quantitative analysis of DNA damage.

STATEMENT OF DR. RONALD O. RAHN, LABORATORY OF MOLECULAR PHARMACOLOGY, NATIONAL CANCER INSTITUTE, NATIONAL INSTITUTES OF HEALTH, BETHESDA, MD; AND BIOLOGY DIVISION, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN

Dr. **Rahn**. I am currently a member of the Biology Division at Oak Ridge, and for the past year I have been a visiting scientist at the National Cancer Institute. My remarks today in no way represent the policies of these two institutions.

I have been asked to present my views on the current job market for people in the molecular-cellular-genetic area of research in biology. This area is widely perceived to be one in high demand in the current job market.

My own background is that of a chemist working on biological problems, particularly those involving DNA and its role in mutagenesis and carcinogenesis.

This subject is very complex, in part because of the interdisciplinary nature of modern biology, and it is very hard to get estimates of who is being trained in what and what sorts of jobs are available because people often wear many hats. We have terms like biophysical chemistry, photobiophysics, physical biochemistry, which all kind of interact, and one can be one of these at any given point in time and another one at another point in time. So there is no good source of statistical information for trying to arrive at any kind of firm conclusions. One has to purely resort to anecdotal information.

One can get some estimate of how many people actually get a Ph.D. in the life sciences or in the health-related sciences and then actually go into academia and receive NIH support and are able to do research. Dr. Bob Wells from the biochemistry department of the University of Alabama at Birmingham figures that about a third of all the Ph.D. graduates, which would amount to about 5,000 per year, actually get into an academic position, and of those, about a third receive NIH funding. So we are down to about 10 percent of all the people getting Ph.D.'s actually getting supported. It is a surprisingly small number, I think.

When you consider the fact that the scores, priority scores now, for getting funding on an NIH grant are now down in the 140's—last year they were up in the 160's—people thought, if I had a 150, I had a good chance; now people are saying, I have to have something in the 140's, so that even among those 10 percent that traditionally were getting research support, now approximately 50 percent of those are being threatened with unavailability of funds.

If the granting level of NIH of 5,000 new investigator-initiated grants per year would be enacted, this would probably reduce by a factor of 2 the ability of young investigators to get support.

Now, this situation results in many people going into industry, taking jobs in industry, not necessarily because of the fact that industry is paying higher salaries, but because they simply cannot do research at universities any longer.

One can read articles that talk about a slave labor market. At Harvard University, you have people doing postdoctoral work essentially for nothing. I know the same situation occurs at Oak Ridge. I know several people down there who had several years of postdoctoral experience, came to Oak Ridge, did a few more years of postdoctoral, and their money dried up. Their wives also had reasonably good jobs there, so they just stayed there; they worked in the lab for nothing, and they really had no flexibility at all. They really had no choice, and there were not jobs available in other places for them to go.

So this perceived notion that the biological life sciences field is one of high demand is pretty much tied in with the fact that in recent years the biotechnology industries have hired a lot of people in the life sciences, particularly those that have capability of doing genetic engineering and can clone DNA.

However, these opportunities, I think, exist predominantly for younger people, new Ph.D.'s. Graduates with 20-year postdoctoral experience, and I think, due to some of the recent cutbacks in the biotechnology industry, that a lot of these people who are gene cloners are out looking for jobs elsewhere.

There are shortages. There is no question that because of the nature of industry, there are needs for people who have experience in plant molecular biology, soil microbiology, and also in this whole business of scaling up and in the processing of the materials.

I think it illustrates the fact that the rate of technology transfer is really limited by the greatest lack of knowledge in any particular one of the interacting disciplines, and that one particular discipline might make a breakthrough, and then it takes a few years, 5 or 10 years in fact, before some of the other disciplines catch up, because everything has to be worked in concert.

You just cannot do one thing. You just cannot have a system which you would be able to clone to DNA. You now have to get the proteins out of the cells. People, when they characterize the proteins, find out that the proteins that are being synthesized often don't have the kinds of properties that they should have. They are difficult to extract from the cells.

There is a tremendous need for people who understand protein biochemistry. There is a tremendous need for people who understand the whole business of how a cell works, I mean, the whole regulation and control processes that are going on in the cell.

The same thing could be said, for example, for cancer research. You can get something like the discovery of oncogenes, and that is a significant breakthrough, but all the other related disciplines that go in to understand how a cell works have to sort of catch up before you can use that information and then do something with it. So things are very complex, and at the bottom is a fundamental, broad knowledge of all things that go together to make a cell work.

Now, my particular concern is that of the midcareer scientist, of which I am one, and particularly at the federally-supported laboratories. I think there are a lot of disastrous situations going on today, and I happen to have been part of one at Oak Ridge.

When I started at Oak Ridge, there were 500 people in the biology division at Oak Ridge. It was probably, next to the NIH, the finest biological institution in the world. Today we are down to about 150 people. Two weeks ago, I received a termination notice: you have 2 months. After 20 years and 70 publications, I get a gold watch and a termination notice.

Well, luckily, I had been looking for a job for 3 years, and I happened to get one on about the day I received my termination notice. But there are a lot of people down there that are not as lucky as I am, and it took me 3 years, and that is the only job I found.

I know for a fact that all of my friends at Oak Ridge have been looking for many years, and there are some pretty outstanding biochemists and molecular biologists, and there aren't any jobs for these people. So I think that this committee ought to look at a situation like that, and it ought to ask itself, to what extent is there a relationship between science policy that is made in Washington and the events that are going on at a national laboratory? Is this something that was planned?

These events and the prediction that this laboratory was going to fold were made last year, in the hearings last year, in the authorization hearings before your subcommittee that has authorizations over the budget and in the year before. You can read written testimony. People were drawing plots and saying, if it keeps going this way, we are going to have to close the place.

It has not closed yet, but the level of 150 was designated as a critical mass figure, and it has now been reached, and I would expect that there would be some kind of reorganization, but the nature of the place will be totally changed from what it once was. So, in effect, it has been lost, and all the institutional memory and its place in history and as a national resource, that is all lost.

A lot of the people who get displaced from that kind of situation often went into paper pushing jobs. There seems to be an abundance of these kinds of jobs. There is all kinds of money to support people to do studies, to analyze regulations and do risk analyses, and so forth. There are divisions at Oak Ridge, the largest divisions at Oak Ridge, the energy division, the information division, huge divisions of people made up of former scientists who do absolutely no research whatsoever.

So I think that with respect to your question on adequacy, how do you focus on adequacy? If you will look at the history of the biology division, it was started 40 years ago to investigate the effects of radiation on biological systems. It took a very broad point of view, and it was quickly realized that DNA was the target for radiation, so there was a tremendous explosion of research in DNA carried out. Some of the discoveries made there, like the discovery of messenger RNA, the discovery of chromatographic methods for separating products of DNA bases, were very fundamental in the subsequent growth of biochemistry, molecular biology, that led to where biotechnology is today.

So if you want to understand what you have to do now to be in an advantageous position 40 years from now, you have to look at what was done there. Basically, you hire good people, you give them all the money they need, and you leave them alone. That is the model with Bell Labs, for example, where I spent 2 years before I went to Oak Ridge. I think it is sort of the bottom line in science policy. I think when you try to fine tune things too much, you really get into trouble. You sort of kill the goose that laid the golden egg.

So I think there ought to be some kind of mechanism, sort of an intellectual flywheel, that would absorb scientists when they get displaced, some permanent funding situation that allows them to retread, to retrain, to stay in sort of an intellectually viable environment and then go out into some other situation.

I think that the scientists that were trained 20, 25 years ago were trained in a much broader way, much more of a fundamental approach in their education than the scientists that are being trained today. I mean, everything is much more complex, so one has to specialize. So if one has a Ph.D. in biochemistry today, he is pretty narrowly trained compared to what a biochemist was 25 years ago, which means a lot of these midcareer people can really more easily fit into a lot of different kinds of situations.

So, to summarize, I think that there is a great waste of human resources taking place today, and I think something should be done about it.

[The prepared statement of Dr. Rahn follows:]

PREPARED STATEMENT OF DR. RONALD O. RAHN

My name is Ronald Rahn and I am currently a member of the Biology Division at the Oak Ridge National Laboratory. For the past year I have been a visiting scientist at the National Cancer Institute. My remarks today in no way represent the policies of these two institutions.

I have been asked to present my views on the current job market for people in the molecular-cellular-genetic area of research in biology, an area widely perceived to be in high demand in the current job market. My own background is that of a chemist working on problems related to DNA damage and repair.

During my efforts to gather information in preparation for this hearing, I was surprised to find that very little statistical data is available on the supply and demand for scientists in this area. This finding is consistent with the point raised previously by this task force in the report dated December 1984, in which it is stated that "in a surprisingly large number of instances very little statistical information now exists to support, or to evaluate, proposed courses of action." This result suggests that perhaps the area of statistics gathering about science might be a good area for some of the AAAS Congressional Science Fellows to become involved in during their stay on Capitol Hill. Perhaps the formation of a National Registry of Scientists would be a useful starting point.

It is safe to assume that the major source of support for long-range, high-risk basic research has been the Federal

Government. This support has been mainly through investigator initiated research carried out at research universities. For example, it is estimated that 85% of the postdoctoral scientists employed at twenty of the largest research universities were involved in Federally sponsored research activities.

Furthermore, the Federal Government has a stated policy that it is committed to the support of long range, high risk research. Hence, it is reasonable that when an individual commits his life to a career in science he assumes that the source of his research support will be through the government. The question then arises as to whether all good scientists deserve to be supported. According to some rough calculations reported by Dr Robert Wells at a hearing held in Birmingham on June 10, only 10% of all of the doctorate level scientists in the health sciences receive federal funding for their projects. And even within this small and elete group, the top half are presently experiencing difficulty in obtaining funding for their research. It seems reasonable to conclude that many good scientists don't get the support they need to continue their research careers.

Employment levels at the universities in the life sciences have increased slightly over the past ten or twelve years. Total growth has been from 88,000 in 1973 to 123,000 in 1984. Furthermore, the enrollment of graduate students in biochemistry, biophysics, and microbiology has changed little over this time, indicating little growth in these specialized areas. Future projections are down for both general student enrollment and for the selection of biology as a major field of study. These factors suggest that faculty positions will be tight over the next twenty years in many areas of basic research.

However, principal manpower needs in the areas of molecular biology and gene expression, virus research, genetics of higher cells, and developmental and cellular biology of animal and plant cells, will most likely occur, based on a growing demand due to jobs created by industry, government and consulting labs. It is expected that normal attrition at academic institutions will allow universities to develop new programs in these areas.

It is my impression that chemistry departments are currently seeking to employ younger faculty members for purposes of training students in areas related to biotechnology. The NSF also supports a 5.3 million dollar program in the "chemistry of life sciences", a program designed to support teams of university chemists and biolgists working in such areas as biotechnology. The National Bureau of Standards is also expecting to develop a program designed to understand at a fundamental level how enzymes function as catalysts. This program will be a key element in the proposed Center for Biotechnology planned in Montgomery County. Of note is the fact that the French Government has targeted research in the application of chemistry to biology as one their nation's top research priorities.

The role of the universities in providing the necessary manpower and fundamental research to sustain commercial development of biotechnology has been well documented in recent reports by OTA, and the departments of Agriculture and Commerce. The ability of the universities to provide these ingredients depends upon the level of Federal funding available and on the quality of the students that enter graduate school. Currently, there seems to be a shortage of both of these factors.

The problem of most concern to those doing research in the life sciences in the threat to reduce the number of new NIH grants to 5000 per year. This level of funding would probably reduce by 50% the number of grants going to young investigators who have not had previous funding. In the universities, as well as in private industry, such a move is viewed as having a serious negative effect on the ability to sustain a viable basic research effort in the life sciences. Not only would the potential for breakthroughs be diminished, upon which the biotechnology industry is based, but also young people would be discouraged from entering a career in science. More scientists would be forced to take jobs in industry resulting in the universities having a more difficult time attracting the best people to faculty positions.

Currently, the job market at Federally supported laboratories is stagnent for those seeking permanent employment. Cutbacks often force mid-career scientists to take desk jobs doing risk assessments, conducting surveys, and sorting out technical information. Consequently, the institutional memory of an organization is lost, and new people are not available to replace those who leave for other jobs or retire.

In recent years the biotechnology companies have been able to hire essentially all of the DNA cloners that the graduate schools have been able to turn out. However, some companies have recently been forced to cutback, and there are currently no great shortages of scientists with this type of training. However, shortages do exist for people with skills in plant molecular biology and in the scale-up phase of bioprocessing. Apparently there is also a need for protein biochemists who can purify and characterize the materials produced in the bioprocessing step.

I believe that there will be an increased need for individuals trained to deal with environmental health issues on a more mechanistic and quantitative basis. Many of these problems which deal with the question of risk can not be approach by conventional animal experiments. A more fundamental approach may be required using molecular mechanisms. The training of an environmental toxicologist, therefore, might require an exposure to more physically oriented coursework.

In summary, the principal manpower needs in the biological sciences will be in the area of molecular biology of complex systems. These needs will be met provided the levels of funding and student quality can be enhanced.

PANEL 2 DISCUSSION

Mr. **Walgren.** Fair enough. You each have provided a real kind of direct cutting edge to what we are experiencing out there, and I think each of your testimonies from the different perspectives from which you come are very useful to have in this kind of search for guidance.

I guess the general question that I would ask each of you to respond to would be something along the lines of the degree of your confidence in us as a Federal Government driving manpower needs or sufficiencies.

Obviously, the market drives it very strongly, as the petroleum industry has shown, and we get into excesses in terms of infringing on people that are already in the field in the practicing engineering area. But could I ask you whether or not you have much confidence in the Government doing something? In a sense, Dr. Rahn says there ought to be a law; you know, there is a problem and somebody ought to do something about it. What is the degree of our confidence in the Government acting in a way that would be helpful, or do you think we should really not try to interfere with these forces that are driving in the petroleum area or the like?

Can I ask that kind of general question and ask for short responses? It is not the most profound question.

Mr. **Brown.** Do you want to start at that end, since the microphone is down there?

Dr. **Rahn.** Well, I think that when people go into research or devote their lives to a research career, they more or less assume that the Federal Government is going to be their source of support. They make a commitment. I think the Government has to make a commitment back to them in some way.

I think that when suddenly funds disappear and people are displaced, and they don't understand why and there is no explanation, you owe something more to them than that, because they have put a lot into their career. It is like somebody trained to be a violinist for 30 years, and then somebody steps on his violin and says you can't play any more. I mean, why? That is the sort of emotional response you have when that kind of situation occurs.

I think there is a lot that could be done about it. Unfortunately, I don't think the Congress has often the time to—well, I think one of the things, if you really look at the number of scientists that are working on science and technology or the total number of former scientists that are employed by the House and by the Senate, it is 10 or 15; I mean, it is a very small number, and a lot of those people never had research careers.

So I think there is a real difficulty in getting information back from what is going on out in the field. I think when you have examiners from the OMB who, let's say, examine, or examiners for the DOE budget in health and environmental research, they are persons trained as physicists, and they are supposed to be making decisions about how much support DOE should give to its biological programs. I mean, that is crazy.

So I think there is an enormous number of places where things can be done to improve the communications. I think the congressional fellows, for example, could be very instrumental in compiling the kinds of data that I think are lacking to come to a better notion of what is going on out there.

I spent a year as a congressional fellow, and there was only one other person, or maybe I was the only person, that served on any of the subcommittees for science and technology. So I didn't really think that we were plugged in. So I think that might be a source of manpower that could be used to get a better feedback.

Mr. **Reed**. I believe that, basically, from the aspect of the working engineer, that we feel that the system works fairly well when it is not being tampered with by the importation or the distortion, if you will, of the marketplace by industry.

We feel, basically, again, that there are enough people. We feel that giving the proper retraining—which very little consideration is normally given to—that we will get along all right.

I think programs such as all the way from Mercury through the current shuttle program, from the B-52 bomber through the F-16, these programs have all used the "in-mobile" type worker. They have all used contract engineering people. I think the success of those programs has been fairly good.

I am not sure that I really have answered your question in the way you are trying to——

Mr. **Walgren**. You say those programs have used the immobile or the mobile?

Mr. **Reed**. They have used—as I understand, the "in-mobile" worker—people from one field moving into the other field. These are the people that they have used. They have made great use of teachers, for example, that have gone into a graduate field and done—you have to understand that most working engineers, their jobs are not what these fellows are discussing. These jobs are basically very mundane, often things such as running the copy machine, such as writing engineering change orders, this type of thing. It is not necessary even to have a college education, let alone an advanced degree, for, I would say, 85 percent of all industry engineering jobs.

From that aspect, we are wasting a tremendous number of highly trained, well educated engineers, by doing these less desirable tasks, if you will. There is a great amount that we could do with those people, but basically they are wasting their education, they are wasting their time, this type of thing.

Mr. **Walgren**. I see.

Mr. Brown.

Mr. **Brown**. Thank you. You have asked if I have confidence in the Government. The implication is to make one proper process that will treat everyone, and my answer is no. I don't think there is anyone in this big, wide world that can make the right decision for me as an individual.

I think there is a role for the Government to play, and it is a major role, in setting up diverse sources of assistance and to meet different purposes in meeting the needs of science and engineering and the parts thereof. But I think that there is a cooperative spirit that has got to be involved. There has got to be a great deal of industry participation, both in the sense of verbiage and in the sense of monetary support. And I think there has got to be a great deal of support from the educational institutions that are involved here.

Then, given the distribution of information to the people who will be the students, who will go on to get these advanced degrees and become our education experts in research in the future, those individuals can make the individual decisions that are right for them.

Mr. **Walgren**. Thank you, Mr. Brown.

Professor Kleppner.

Dr. **Kleppner**. Without wishing to seem insensitive to the issues that Dr. Rahn raised, which are quite real, I would like to address another aspect of the scientific manpower in the future, which is the continued strength of the universities. If our educational systems do not maintain their level of excellence, then we are going to have manpower problems in the future, certainly, and I think that the Federal Government has a very direct role to play there, because the training of scientists depends upon the quality of research level in the universities.

Mr. **Walgren**. Let me ask you, you indicated in your testimony that there was going to be this increase in demand, and yet your numbers were from 750 to 1,200 new openings, and I couldn't tell whether it was over 1 year or over a 5-year period.

But that seems a relatively finite number, and when you say we want to keep the excellence of the university, are we training all these people just to provide 3 percent of them with an opportunity, and would the rest be told that they are not worth what they were shooting for and what they aspired to? Is that a danger we are running into?

Dr. **Kleppner**. In my written testimony, I tried to summarize some of the features of this manpower study, and I think I did not do it very clearly, because these numbers are confusing. I think one should look at the study itself, particularly the graph at the end, and the conclusion, which is this precarious balance through the nineties and then a likely shortage.

Now, the shortage will be due to a number of factors, but a major factor there will be a rapidly increasing market for faculty members. That is a major source of employment in physics—well, in all of sciences, particularly in physics—and the number of openings is documented there.

The conclusion of the report is that there is likely to be a shortage. Now, what that means is that there will be more competition for the people who are available, that one will try to get whoever is available for these jobs. It will not be a satisfactory situation because universities will have lost their flexibility to choose those members who they think are the most outstanding.

This is what I am concerned with. My concern is that the very best young people will no longer be looking to universities as one area to pursue their careers, and I think there is some indication that this process is starting to take place.

I mentioned the shortage of condensed matter physicists, experimental physicists, which is very pronounced. Many universities report on this, and this is an indication of what one can expect in the future. These people seek other careers in industrial laboratories where they can pursue the research that they want, and so they are turning away from the universities, and the universities cannot hire them.

This process may expand to other areas in the future, and it is this erosion, or that this could lead to an erosion of the faculty, which I think is of concern, and I think it is a proper concern to the Federal Government, because university research is fundamentally the responsibility of the Federal Government.

Mr. **Walgren**. Well, on behalf of the task force, and having lost our second member there, are there other questions we should raise? I believe Mr. Mineta had questions of this panel, and we don't want to short-circuit his ability to raise them.

I am interested in the idea that we do hold out at least more than a promise to these people we want to come into the scientific community, and then if we don't have at least relevant opportunities for them, we have misled them.

I am remembering anecdotally a fellow who was pursuing a Ph.D. in physics and just couldn't make it through that process to find opportunity and wound up really sort of punched in the solar plexus and directed off into another very good career but, nonetheless, not what he had trained himself for. I guess I am wishfully thinking that we had some communicative mechanisms where people were not left so completely in the lurch where their only opportunity is then to almost beg to be picked up in other parts of the economy, and that is a difficult position for anybody to be in.

Mr. **Brown**. But, by the same token, you can go back and look at the petroleum industry as an example. Since 1975, the Society of Petroleum Engineers has had a forum where we could get differing opinions as to what was going on. The first thing that has been done in starting that, there was a paper in the annual meeting in New Orleans in 1975 saying, "Hey, fellows, start thinking because you are going into another boom, and there is going to be a bust."

Since that time, each year, information has been made available to students, and educational groups are part of the activity, and they have been told, You darn well know the industry cannot continue to use expanding numbers every year. At some point in time, there is not going to be a market for that thing, and the individuals have to be given that opportunity.

I strongly feel that there is no guarantee in life that says I may go take a degree in a certain field, and I will always have a career in that field. I think there is a lot of history that says, especially in the last few years, that individuals are going to have multiple careers, not necessarily in totally diverse activities but in specialties within related fields. I really think you will get yourselves in all sorts of Orwellian complexes if you try to set up a group, an individual, at one point that says we guarantee that if you will enter this field and get your degree, you will always have a job in that field.

Mr. **Walgren**. But, to a certain degree, don't we say, "Please enter this field, because we want you to, and we want you to develop this training, and we value that capacity, "and then, at a later point in that same life, we are saying that was true back then, but it is not true now, at least not to provide circumstances for you.

Mr. **Brown**. That may well be. I will go back and use a personal example. My background is not petroleum engineering; my background is chemical engineering. The best opportunity when I graduated came about in the petroleum engineering field.

When I told you that the petroleum industry hires less than 50 percent of the petroleum engineers, that is true. Back in the years, in the sixties and early seventies, when they couldn't hire as many petroleum engineers as they wanted, they were hiring mechanical, chemical, and a whole host of others and providing the training and development for them.

Mr. **Reed**. Could I add just a little bit to that? Back in late 1969 and 1970 and 1971 and so on, there was a huge crash in the market for engineers. There were something in the order of 100,000 engineers out of work during that period of time.

Currently, the electronics industry is facing one of the greatest periods of crisis within its history, on top of, or being supported by, the defense industry. I think everybody here will agree that one of these days before very long, we are going to cut defense spending, and it is going to be cut drastically. We are going to have another 1970 when that happens. We are going to drive another 100,000 engineers out of the profession, and we are going to have another crisis, and we are going to have to train more engineers; we are going to have to enlarge the schools and the whole thing again.

I think that if there is any way to modify these huge spikes and huge valleys within the profession, I think perhaps through funding in defense or something—you know, this is your area of expertise, not mine—but I think there is something that perhaps could be done there without the direct intervention on an individual basis.

Mr. **Walgren**. Mr. Mineta.

Mr. **Mineta**. Mr. Chairman, if you would yield, I was just wondering whether or not—there are two parts of this, I guess. One is I am looking at this exhibit 3 on your testimony, Mr. Brown. The number of wells being drilled and the need for petroleum engineers seems to parallel pretty much as you go along. Is there a correlation there?

Mr. **Brown**. Oh, yes. It is very dramatic. Wells are drilled when optimism exists, where there is a good spread between the prices received for your oil and gas and when the costs of getting it are not that great.

Mr. **Mineta**. Let me go back, then, to the other point that Mr. Reed makes. I am wondering whether or not, as a country, we have to absorb some of those as standby costs as we go through the peaks and valleys. We have a fire department, but we don't use the fire department all the time. We need them, and it is a standby cost that we have to pay. I am just wondering whether, as we go through these peaks and valleys, we just don't have to absorb that cost in society, both from a human resource perspective as well as from a dollar perspective?

Mr. **Reed**. I think that perhaps we should not base our projections on the very peak years. I think that would have a great effect on this, a leveling effect.

I think that I have mixed emotions about whether we ought to try to support the people who are not currently being supported in industry. Basically, I am against that sort of thing, but at the same time, I feel that the engineering profession and the science and all are so terribly important to the future of the country that—I don't know. Maybe there is something else they could do for a couple of years.

Mr. MINETA. When we had that big aerospace cutback there in that, let's say, 1969-70 period, and then about, oh, 1978 or so, when Boeing was looking for engineers for the 757, 767 new generation aircraft coming on board, frankly, as I got the feeling, they didn't want to hire people; they wanted to contract to have a body who was especially trained for some specific task. They didn't want to hire all these people because they had gone through that experience of hiring a lot of people and having the aerospace cutback come in 1969, 1970. Now in this new era where they were putting together the 757 and 767, they just wanted specialty people for a short period of time, and they were contracting with, in effect, labor contractors who were specializing in engineering professions that Boeing needed.

Mr. REED. Yes, sir. I work in that way. I am very familiar with it.

Mr. MINETA. Are you saying that that is not a good way to go?

Mr. REED. No; I am saying that I think that is a good way to go. Let's make use of the temporary, "Kelly Girl" type operation.

Mr. MINETA. Now, does that require a national registry of scientists and engineers so that, you know, "Have bag, will travel" to wherever the jobs are?

Mr. REED. No; the industry is there and in place at this time. It is my understanding—and I am not that much of an expert on that industry—that there is somewhere in the area of 125,000—as distinguished from specific degreed engineers—engineering workers, OK?—that are very mobile people. They are willing to pack up from the D.C. area, for example, and move to Seattle next week.

I know many engineers who have tried to get on at Boeing in the 757 and 767 times and had an extremely difficult time trying to get a job.

Mr. MINETA. I come from an area that is known as Silicon Valley. What is happening in the semiconductor industry, there are large numbers of potential layoffs coming now, and there is going to be a large dislocation.

Mr. REED. Absolutely.

Mr. MINETA. I wonder whether the aeronautical engineer isn't maybe the cutting edge of what we are going to see happening in the semiconductor industry in the next 3 to 5 years.

Mr. REED. Yes; I think that to an extent that will be true, that you will see these people going off into another industry as they are able to make the transition, and then, if times get better in the electronics industry, they will be coming back.

To date, I don't believe that anybody has said we don't need any more engineers in the electronics industry, in spite of the massive layoffs. I cannot believe that they can layoff somewhere in the area of 100,000 people the first 6 months of the year and not have laid off some engineers. You know, there is a certain ratio between engineering and production workers that is normally maintained. So those people are going to have to go someplace, you know; they have got to make a living. I am not sure I have answered your question, but I believe that many of those people could make the transition into the contract engineering field.

Mr. **Mineta**. Thank you, Mr. Chairman.

Mr. **Walgren**. Thank you, Mr. Mineta.

Well, on behalf of the task force, let me thank each of you for the perspectives that you have given and the contribution you have made to the record. We appreciate that very much. Thank you.

The task force will stand in recess until 9:30 tomorrow morning in this room.

[Whereupon, at 12:19 p.m., the task force recessed, to reconvene at 9:30 a.m., the following day, Wednesday, July 10, 1985.]

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SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

WEDNESDAY, JULY 10, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
TASK FORCE ON SCIENCE POLICY,
Washington, DC.

The task force met, pursuant to recess, at 9:34 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. FUQUA. The hearings continue today on "Scientists and Engineers: Supply and Demand."

We have a panel of four distinguished witnesses who will testify on the funding mechanisms for supporting graduate education. Our witnesses represent two givers of funds and two takers.

We want to explore the relative effectiveness of the various funding mechanisms; looking not only at how many graduates are produced by various mechanisms, but also at other effects—such as relative effects on geographical distribution of graduate students.

We will ask each witness in turn to give a brief summary statement and then we'll get into the questions and answers with the whole panel.

Our first presenter will be Dr. John Moore, the Deputy Director of the National Science Foundation. He will be followed by Dr. Robert Hill, chairman of the biochemistry department at Duke University, who will describe the NIH funding programs. And the next presenter will be Dr. Clarence Ver Steeg, dean of the graduate school at Northwestern and the concluding witness will be Dr. Karl Willenbrock, professor of engineering at Southern Methodist University who will discuss the issue from the point of view of the universities.

So, we're very pleased to begin with our first presenter, Dr. Moore.

STATEMENT OF DR. JOHN H. MOORE, DEPUTY DIRECTOR, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC

Dr. MOORE. Thank you, Mr. Fuqua. I will try to be as brief as I can. I want to thank you for the opportunity to come here today and discuss graduate science and engineering education, which is of course one of the very important subjects for us all. I will, during my remarks, be referring to some figures that are attached at the back of my testimony and so if you would have those available.

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What I want to do today is present some information on trends in graduate education and its funding and I'll begin by talking just for a moment or two about the size of the enterprise that is involved here.

There are presently about 325 institutions granting doctorates in science and engineering; another 275 that grant master's degrees only. The total graduate enrollment in science and engineering this fall is about 400,000 students, fall 1983, I'm sorry, is 400,000 and it is of some interest to note that of that total about 150,000 are women. The full-time enrollment in that same year was nearly 264,000 of whom 91,500 were women. This year there are about 18,000 doctorates in science and engineering being awarded and about 60,000 master's and other graduate degrees.

I think it is also important to note that participation of minorities in this is not what we would like it to be, I think. Of the doctorate recipients about 2 percent or 325 were black, 1½ percent or a little less than 300 were Hispanic. Another point I think we should bear in mind is that nearly 24 percent of full-time enrollment consisted of foreign students; 20 percent of all science and engineering doctorates in 1983 were foreign nationals without permanent residence in the United States. And if you include the number of immigrants in that total it rises to about 25 percent.

The full-time faculty in doctorate-granting institutions is about 140,000. It's a little hard to assign them to teaching and research, but that's the full-time total.

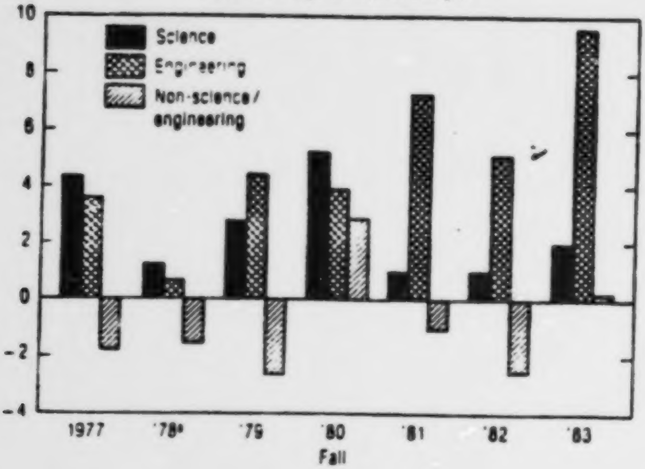
If you would put this in a little perspective, begin by looking at viewgraph No. 1, which shows the annual percentage changes in graduate science and engineering enrollment—it's not a viewgraph anymore, it's a chart—you will see that between 1977 and 1983 graduate engineering enrollments rose quite rapidly, but other sciences rose more slowly. Between 1980 and 1983 enrollment in the sciences grew at less than 2 percent per year. Full-time foreign student enrollment in the sciences and doctorate granting institutions has grown rapidly. In fact in the sciences U.S. citizens full-time enrollment declined between 1976 and 1983.

Viewgraph #1

Graduate enrollment in the sciences and engineering

Annual percent change in graduate enrollment by field

Percent change from previous year



aIncluding interpolated data for master's granting institutions

SOURCES: National Science Foundation and Department of Education, National Center for Education Statistics

The next chart, chart 2, shows the distribution of full-time graduate science and engineering enrollment in doctorate granting institutions by a source of major support, and I think you'll notice there has been little change between 1976 and 1983. Institutional support grew slightly. Self-support and Federal support for graduate students fell slightly. Referring to Federal support, in 1983 about 47,000 science and engineering graduate students received Federal support.

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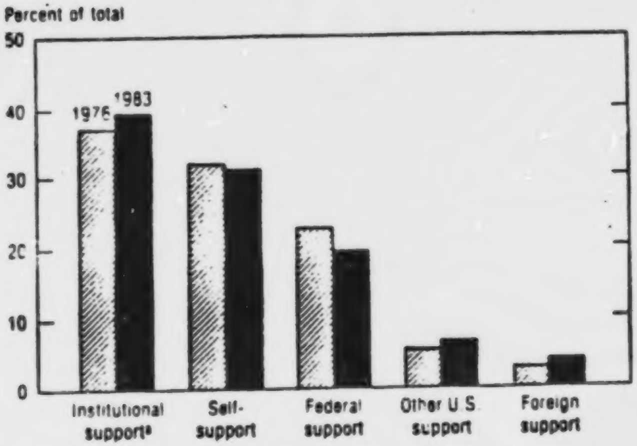
Viewgraph #2

Distribution of full-time graduate science/engineering enrollment in doctorate-granting institutions by source of major support

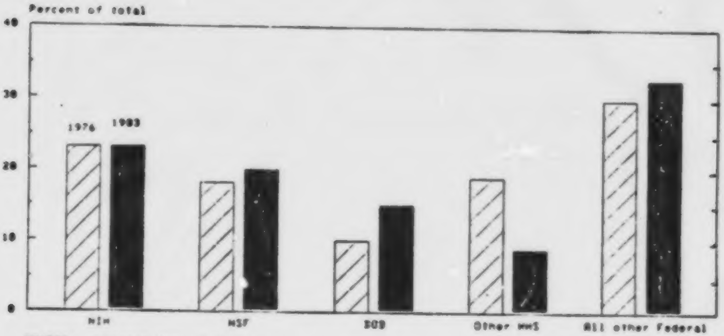


[a] Includes support from State and local governments
SOURCE National Science Foundation

The Federal component is broken down in figure 3, at least by NIH, NSF, DOD, and other HHS support. You can see from that chart that the NIH support remained quite constant between 1976 and 1983; NSF grew slightly; DOD significantly; other HHS fell and all the other Federal stayed about the same.

Viewgraph #3

Distribution of federally supported graduate students by agency

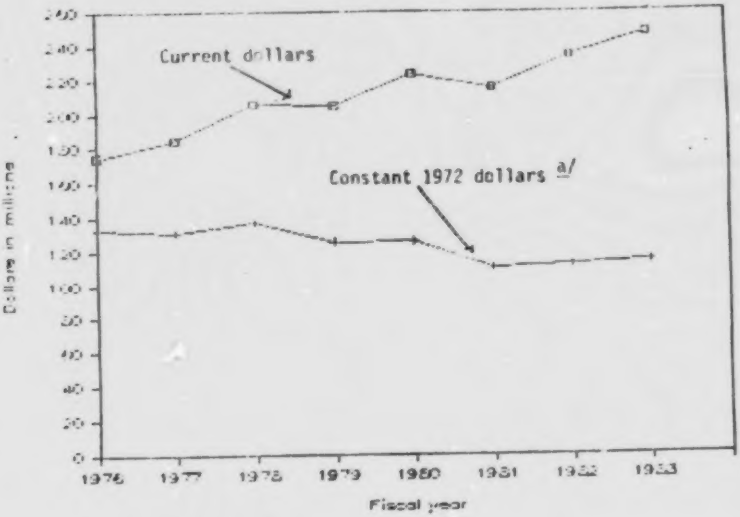


SOURCE: National Science Foundation

The amount of Federal support in current dollars rose from about $175 million in 1976 to nearly $250 million in 1983, which is an increase of about 41 percent. But, as chart 4 shows this increase was affected sharply by inflation. In constant dollars, Federal support over this period fell by 14 percent, approximately. That decline ended in 1981. There were small real increases in the subsequent 2 years.

Viewgraph #4

Federal obligations for fellowships, traineeships, and training grants



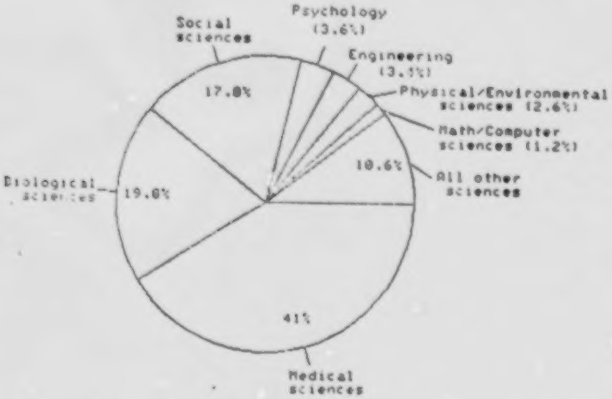
a/ Based on GNP implicit price deflator.

SOURCE: National Science Foundation

Federal support for graduate science and engineering has favored generally the medical and biological sciences, as chart 5 shows. That distribution has remained quite constant over the period between 1976 and 1983. The major shift, if there was one, was within—was between medical and biological sciences, but the total for biological and medical remain about the same, that is to say the total for life sciences remained about the same between those 2 years. From NSF's standpoint I suppose it's interesting to note the relatively small share of physical science mathematics, computer science and engineering in that total.

Viewgraph #5

Distribution of Federal obligations for fellowships, traineeships, and training grants by field: FY 1983

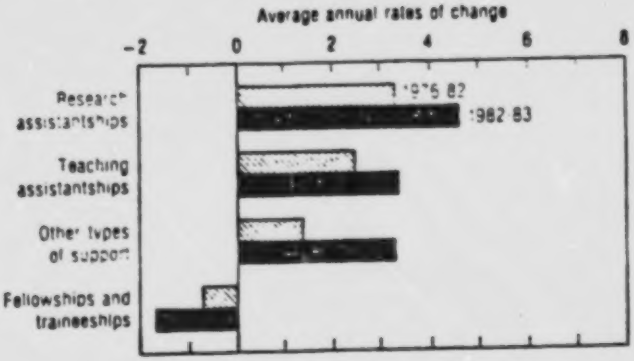


SOURCE: National Science Foundation

Support to graduate science and engineering students has changed its form, and chart 6 is intended to illustrate that. It shows that there has been a steady decline in support in the form of fellowships and traineeships since 1976, in fact. And especially between 1982 and 1983 there was an even greater decline, whereas there has been an increase and support afforded through research assistantships, teacher assistantships and other forms of support. Of course the shifts from fellowships and traineeships to RA's and TA's suggests a reallocation of student time, which is something at least to be considered.

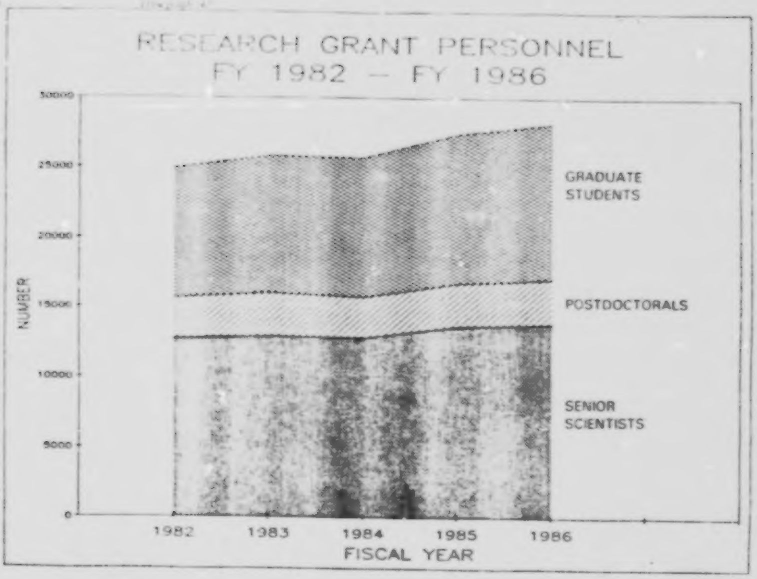
Viewgraph #6

Full-time graduate science/engineering enrollment in doctorate-granting institutions by type of major support



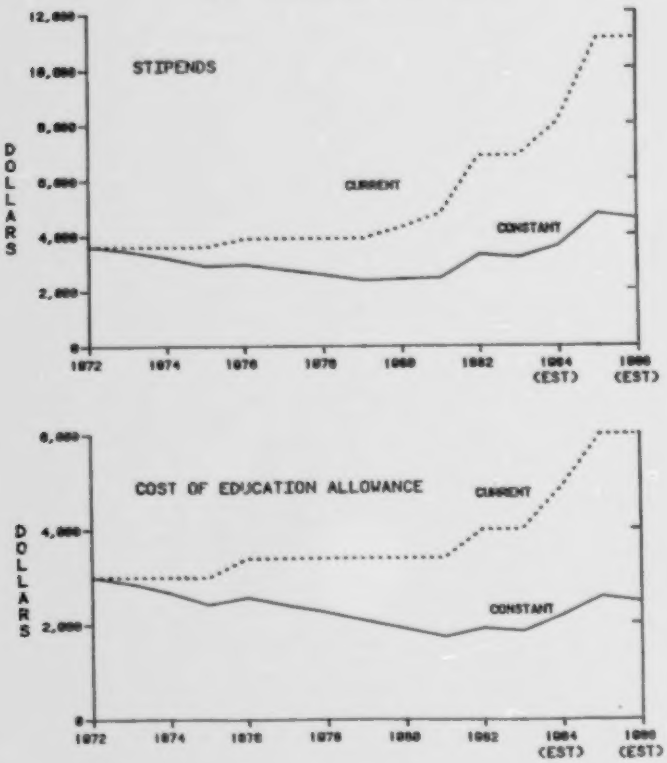
SOURCE National Science Foundation

Now, for a moment I'd like to just shift a bit more parochially to NSF's programs and I would mention to begin with that the Foundation would believe very strongly in the connection between research and education and in the importance of keeping those things together. And I think you can see that graphically in chart seven. That presents the situation between 1982 and 1986 and indicates that the number—and this chart is in terms of numbers of people—the number of graduate students and postdoctorals supported on NSF research grants is typically as large or larger than the number of senior scientists supported on those grants. And this, by the way, is the major source of support to graduate education in the Foundation.



The number of graduate students that would be supported in fiscal 1986, under our request, would be about 10,700. And the total amount of support right now is about 100 million and it would rise in fiscal 1986.

I want to emphasize that this support in the way—and growing support for graduate students under research grants does not come at the expense of the fellowship program. NSF, in 1985, made about 1,560 fellowship awards. That number is up from 1,300 in 1980. Stipends and cost of education allowances have increased. For 1985 the stipend is $11,100, which is nontaxable. The cost of education allowance is $6,000. Now, these are substantial increases over the situation a few years ago, but again inflation has to be taken into account. The chart—the next chart, chart 8, shows what has happened to both the stipends and the cost of education allowances in both current and constant dollars. The stipends have done fairly well, vis-a-vis inflation. There has been an increase in the real value of the stipend, but the real value of the cost of education allowance has declined. I also mention that in fiscal 1986, according to our request, the cost of the fellowship program would be about $27.3 million.



Viewgraph #8

NSF GRADUATE FELLOWSHIPS

I'd like to spend a minute or two talking about a few problems in graduate science and engineering education and begin with the pattern of doctorate production. The number of doctorates in science and engineering peaked around 1970. It fell thereafter to about 1978 and has risen slightly since that time. And I've already mentioned the full-time—the current situation regarding full-time graduate science and engineering enrollments. But they rose slowly from 19—they have risen recently from their recent low point in 1979. But, there has been a concentration of these people in master's program. Thus although master's production has grown the increase in doctorate production has been smaller, and in some cases declining.

The next chart shows that this problem is not uniform, if it is a problem, by field. I would mention that these data include foreign students. The decline—there have been declines in the production of doctorates since 1970 in every field except computer science and the computer science and the computer science figure may be slightly misleading because it began at a very small base in 1970.

Viewgraph #9

GROWTH RATES OF S/E DEGREES BY LEVEL AND SELECTED FIELD: 1970-82

	Bachelor's	Master's	Doctorates
		(Percent)	
Physical science	1.0	-0.6	-2.3
Engineering	3.5	1.5	-1.7
Mathematics	-6.9	-5.9	-4.8
Computer science	24.0	10.7	7.4

Source: National Center for Education Statistics and National Science Foundation

There has been a relatively rapid increase, you will notice over a considerable period of time in enrollment—undergraduate enrollments and degrees, in this case, in engineering. And I'd like to spend just a minute on engineering and I know that we're going to hear a lot more about engineering in a few minutes. But, I will make a couple of points in this respect too. And computer science.

Graduate enrollments have increased in both engineering and computer science, but with out a commensurable increase in doctorates. And of course there has been vigorous competition from industry for the doctorates that have been produced in both those fields. In 1983, according to one survey, only 55 percent of new engineering and computer science Ph.D.'s planned academic employment. There also have been very rapidly increasing undergraduate enrollments in both of these fields and the result is that at least in certain subsets of these fields, there are faculty shortages.

I would also like to make special mention of mathematics because mathematics is a science of central importance to all of science and engineering. There the production of doctorates has declined for the last decade, even including foreign students. According to recent studies the field will not be able to replace its existing faculty with doctoral—doctorate holders at present degree production rates. And I think that's a matter of some serious concern.

A lot of this is of course a result of simple economics. What we're seeing is the result of simple economics. When students now come out of their bachelors training they can choose between immediate employment or further academic work. And I suppose no one here needs to be told, but I will anyway, that it generally pays to go into industry at that time for graduates with bachelors degrees in science or engineering.

Chart 10 gives some data on that. It shows the average starting salaries in industry, as opposed to the NSF fellowship award that would be available, provided a student could get one. Now, the NSF—it is also important to notice or to point out that the NSF fellowship stipend is probably above average for graduate students support. There are other fellowships that are larger, but NSF—the NSF is a good one. It's a very competitive fellowship. This year we were able to fund only about 13 percent of the applicants for the fellowship. Looking a little bit further into the future graduates thinking of the academic alternative has to consider academic salaries. And also on chart 10 there salaries in various fields for assistant professors. And of course it has to be borne in mind that that is 6 to 8 years down the line for the fresh bachelors graduate. Not only that, and of course now I'm talking from the standpoint more of academic science and engineering than that of industrial, but industrial demand for Ph.D.'s in some fields is extremely strong. This is reflected in high salaries, better facilities, in many cases for research, the absence of teaching requirements and perhaps other benefits that make industrial employment appear very attractive to at least some Ph.D. graduates.

Viewgraph #10

COMPARISONS OF AVERAGE STARTING SALARIES: 1985

	B.S. Candidates	NSF Fellowship Stipend	Assistant Professors
Chemistry	21,800		22,000
Mathematics	23,900	11,100	23,000
Computer Science	24,600	Non-	27,000
Engineering	27,000	taxable	29,000
Biological Science	17,200		22,000

Source: National Science Foundation and College and University Personnel Association

So, those economic forces are not very encouraging as far as academic research or even our research base is concerned. However, economic forces can also work in other directions. The upsurge in undergraduate enrollments in engineering and computer science reflect the response of students to the career opportunities they are facing. These shifts in demand should be reflected in faculty recruiting in universities at some time, and indeed, I understand there has already been some response in faculty salaries. And that again, they should be reflected in graduate enrollments in fields that are now thought to be in short supply.

I think we, in trying to frame policy responses to this situation, should be careful that we do not oversupply personnel in particular areas in the future. I would just end, and I'm sorry to have taken so long, by mentioning the fundamental question I think we have to face, which is whether we are creating enough scientific and engineering talent to provide the research base necessary to meet increasing international competition, both economic and military, that we will be facing in the future.

And I thank you very much for your attention.

[The prepared statement of Dr. Moore follows:]

Prepared Statement of Dr. John H. Moore

Mr. Chairman:

I wish to thank you for the opportunity today to discuss with you the important subject of graduate education in science and engineering. NSF carries out a broad array of activities consistent with our overall mandate to promote the progress of science. The obligation of the overwhelming portion of our basic research support funds to colleges and universities reflects the inseparable link between science and engineering education, particularly at the graduate level, and high-quality basic research in science and engineering. We strongly believe that such a coupling is essential for continuing the scientific and technological leadership of our Nation into the future. In the brief time I have with you today I should like to provide some information regarding trends in graduate education in science and engineering and financial support for this critical area.

First, how large is the enterprise that we are talking about? At the level of the Ph.D. in science and engineering, the principal research degree, there are today about 325 doctorate-granting institutions. When master's-only institutions are added, this number rises to more than 600. Total graduate science and engineering enrollment in Fall 1983 was over 400,000 including both full- and part-time students. Of this number, somewhat more more than 150,000 were women. Full-time enrollment was nearly 264,000. About 18,000 Ph.D. degrees in science and engineering were awarded this year and another 60,000 master's and other graduate degrees. Minority participation was disappointing. Of the Ph.D. recipients, an estimated 2% or about 325 were Black and 1-1/2% or about 290 were Hispanics. Also to be noted is the fact that almost 24% of full-time enrollment in 1983 consisted of foreign students, and that 20% of all doctorates in FY 1984 were awarded to foreign nationals without permanent residence status in the United States. The number of teachers actively involved in the graduate education of these students is less precisely known, but the total full time science and engineering faculty in doctorate-granting institutions in the fall of 1983 was approximately 140,000. The cost of graduate science and engineering education in the United States is also not precisely known, but the total expenditure of all institutions of higher education is in the vicinity of $100 billion annually.

These figures are impressive, but for proper understanding it is necessary to put them in the perspective of trends in recent years. Figure 1 shows the annual percentage changes in graduate enrollments at our colleges and universities in the years from

1976 through 1983. Graduate enrollments in engineering rose at sigificant rates. Other sciences generally have grown at smaller rates; between 1980 and 1983, the annual rates of increase were less than 2%. Full-time foreign student enrollment in the sciences has risen substantially more rapidly than enrollment of students with U.S. citizenship; indeed, among full-time students in doctorate-granting institutions, U.S. citizens' enrollment in graduate science actually declined between 1976 and 1983.

Graduate students in science and engineering obtain their support from a variety of sources, as the data presented in Figure 2 indicate. The ranking of sources has not changed since 1976, but institutional support has become more important relative to other sources, while students' own resources and federal support have declined relatively. In 1983, just over 47,000 graduate students in science and engineering received support from federal sources. Figure 3 shows how the students supported by federal funds were distributed in 1976 and 1983 by several of the major funding agencies.

Between 1976 and 1983, federal support to graduate students, in the form of fellowships, traineeships, and training grants, rose from approximately $175 million to $247 million in current dollars, an increase of 41%. Taking inflation into account, however, changes this picture; in constant dollars, federal support fell by 14% during this period (see Figure 4). The decline in real support ended in 1981, and there were small increases in the succeeding two years. The allocation of federal support for graduate students in science and engineering, in fellowships, traineeships, and training grants, generally favors the medical, biological, and social sciences, relative to the physical sciences, engineering, and other sciences, as Figure 5 demonstrates. (There has been little fundamental change in this distribution in the last decade, although there has been a shift between medical and biological sciences.) The relatively small shares of the physical and mathematical sciences and engineering are noteworthy. One feature of the distribution cannot be shown on the figure because of its small size: federal support for graduate students in computer science, which totalled less than $75,000 in every year until 1983, and even then was less than one million dollars.

The types of support available to graduate students have changed in recent years, as shown in Figure 6. There was a drop between 1976 and 1983 in the number of students supported by fellowships and traineeships, a drop attributable almost entirely to the continuing reduction in federal support of this type.

Corresponding to the enhanced support role of the university is an increase in the number of students receiving teaching assistantships. The significance of this is difficult to judge; the shift suggests a reduction in full-time attention to formal study. On the other hand, the time spent in the classroom or laboratory under an assistantship can provide highly valuable experience. After all, many are headed for research and teaching careers at universities.

Support of graduate education in science and engineering is an important and longstanding element in the programs of the National Science Foundation. As the Federal agency with the unique mission of insuring the long-run health of all of science and engineering, NSF has mandated responsibility for both research and education. The Foundation's research programs provide support for a great many graduate students, and the NSF Graduate Fellowship program has an unsurpassed national reputation for excellence earned over the almost 35 years of its existence; it has supported nine Nobel laureates.

Figure 7 presents one way of seeing NSF's belief in the inseparability of research and education in action; the number of graduate students and postdoctorals on NSF grants is typically equal to or larger than the number of senior scientists. As the figure indicates, the number supported under NSF research grants is much larger than the number of NSF fellowships; we estimate that our FY 1986 request would provide partial support to about 10,700 graduate students, making the total support provided through NSF research grants amount to slightly more than $100 million. In Fy 1985, NSF awarded 1,560 fellowships, up from 1,300 in 1980; however, we were still able to fund only 13% of the new applicants. The FY 1986 request would continue to support about the same number of students at a total cost of slightly more than $27 million. NSF Graduate Fellow stipends and cost-of-education allowances have increased in nominal terms in the last few years, as shown in Figure 8, but once again the impact of inflation was severe in the latter 70's. Recent increases in stipends have kept them well ahead of inflation, but cost-of-education allowances have not kept up.

NSF post-doctoral awards and the Presidential Young Investigator Awards Program make important contributions to the strength of science and engineering education in more ways than one. The Presidential Young Investigators Awards provide outstanding younger faculty members with assured research support for periods of five years; the program will, as of FY 1986, maintain 500 young investigators annually at a total cost of just under $30 million. The direct impact of these programs on the professional development of their recipients is obvious, but these awards also make the academic career more appealing and thus help to encourage other young people to adopt it.

Let me turn now to a few problems, because looking only at the averages produces an impression that may be overoptimistic. It is when the data are examined in closer detail that certain weaknesses emerge.

The number of doctorates awarded in science and engineering peaked around 1970, fell thereafter until about 1978, and has risen only very slightly since then. Full time graduate enrollments in science and engineering have risen slowly from the most recent low point in 1979, but enrollment increases have been concentrated in the master's degree programs. Thus, while master's degree production has grown, the increase in doctorate production has been substantially smaller. Of course, the fundamental research base for both academics and industry depends on those with the training and skills reflected in the doctorate, and the earlier decline and recent slow growth in that area have potentially serious ramifications. The potential problem is not uniform by field of science, as Figure 9 shows. Even computer science, shows weakness in the production of doctorates relative to bachelor's and master's degrees awarded.

The situation in academic engineering and computer science requires additional comment. Again, the increase in graduate enrollments in these fields has not led to a commensurate increase in doctorates awarded. (The relatively rapid percentage growth rates in computer sciences are measured from a very small base; counting doctorates in both computer science and computing theory, a degree now awarded in mathematics departments, the total in 1984 was 308.) Furthermore, there has been vigorous competition from industry for these graduates. In 1983, only about 55% of new engineering and computer science Ph.D.'s planned academic employment. The result, according to a study recently published by the Scientific Manpower Commission,* is faculty shortages in both fields. Combined with rapidly rising undergraduate enrollments in these subjects, student-faculty ratios have risen sharply, creating pressure on faculty time. The impact on research is difficult to assess without detailed study, but is an issue worth consideration.

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*Betty M. Vetter, The Technological Marketplace: Supply and Demand for Scientists and Engineers. Scientific Manpower Commission, May 1985.

Special mention should also be made of mathematics, where the number of new doctorates has declined for the last decade. Present levels of production are such that the field cannot fully replace its retirees with doctoral degree holders. By the 1990's, when retirements of present faculty accelerate, the situation may well be even more problematical. The central importance of mathematics to fundamental advances in science and engineering, and its great potential for practical applications, make this an especially noteworthy matter.

We have seen that graduate enrollments in the sciences have grown slowly in recent years, while those in engineering have grown more rapidly. If enrollment of foreign students is deducted, there has been very little increase in graduate engineering enrollment until very recently. Furthermore, an increasing fraction of those now enrolled in graduate work continue only as far as the master's degree. Thus the production of doctorates in both the sciences and engineering as recently as 1983 remained below the level of a decade earlier. Between 1980 and 1983, there was a small upturn in doctorate production; the annual rate of increase was 1.4%. Whether this will be sustained or is an adequate rate of increase is unknown.

To a degree, these results reflect simple economics. The bright student graduating with a B.S. degree can choose between immediate employment and further academic work. On average, there is no question which choice will bring the greater financial reward. Figure 10 presents some pertinent data on average salaries. By comparison, the stipend for an NSF graduate fellowship in 1985 is $11,100 (which is, of course, nontaxable). Some other fellowships have larger stipends, but the NSF figure is above average. Of course, not every B.S. graduate can land a fellowship or assistantship.

But the choice is not, of course, based completely on a simple comparison of the immediate financial alternatives. The student will look ahead to the culmination of the graduate program, perhaps four to six years in the future. At that time, the academic alternative is that of an assistant professor's salary, which is not outstanding, as the figure shows. Of course, industrial alternatives will open up at graduation as well, with better salary (especially in engineering and computer science) and very often more advanced and better equipped research facilities, which can be decisive.

Economic forces are also at work in other directions. The rapid upsurge in undergraduate enrollments in engineering and computer science reflect the response of students to the career opportunities they face. These shifts in demand ultimately should be reflected in faculty recruiting at colleges and universities, and, with some lag, in graduate enrollments in fields that are now regarded as being in short supply. Any policy response to currently perceived shortages should be carefully framed so that it does not overshoot the mark, possibly leading to future oversupply of graduates in particular areas.

A fundamental question to be faced is whether the production of Ph.D.'s will be adequate to provide the research base necessary to meet growing international competition, both commercial and military. It is a complex and difficult matter worthy of the careful attention of all those involved in the policy formation process.

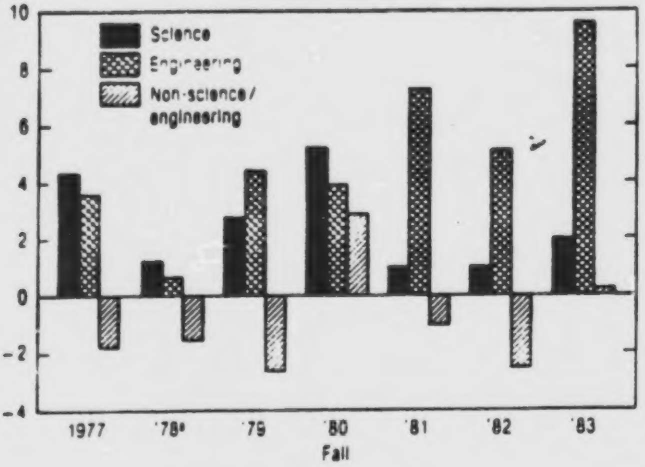
Mr. Chairman, this concludes my formal remarks. I would be happy to respond to further questions.

VIEWGRAPH LISTING

1. Graduate enrollment in the sciences and engineering.
2. Distribution of full-time graduate science/engineering enrollment in doctorate-granting institutions by source of major support.
3. Distribution of federally supported graduate students by agency.
4. Federal obligations for fellowships, traineeships, and training grants.
5. Distribution of Federal obligations for fellowships, traineeships, and training grants by field.
6. Full-time graduate science/engineering enrollment in doctorate-granting institutions by type of major support.
7. Research grant personnel FY 1982-FY 1986.
8. NSF Graduate Fellowship Program Stipends and Cost-of-Education Allowances Current-Year Dollars and 1972 Dollars.
9. Growth Rates of S/E Degrees by Level and Selected Field: 1970-82.
10. Salary Comparisons.

Viewgraph #1

Graduate enrollment in the sciences and engineering



Annual percent change in graduate enrollment by field

Percent change from previous year

[a] Including interpolated data for master's granting institutions

SOURCES: National Science Foundation and Department of Education, National Center for Education Statistics

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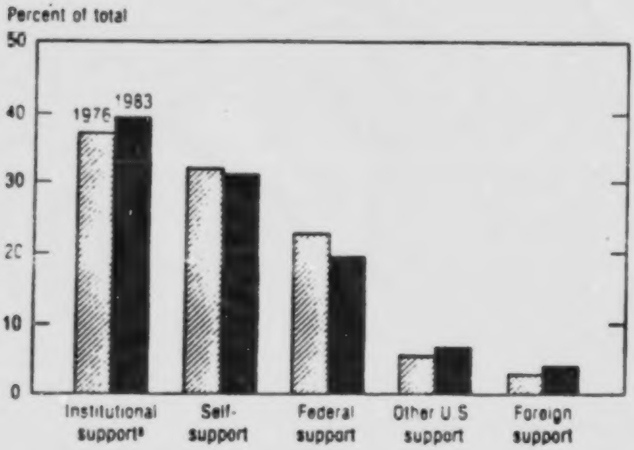
Viewgraph #2

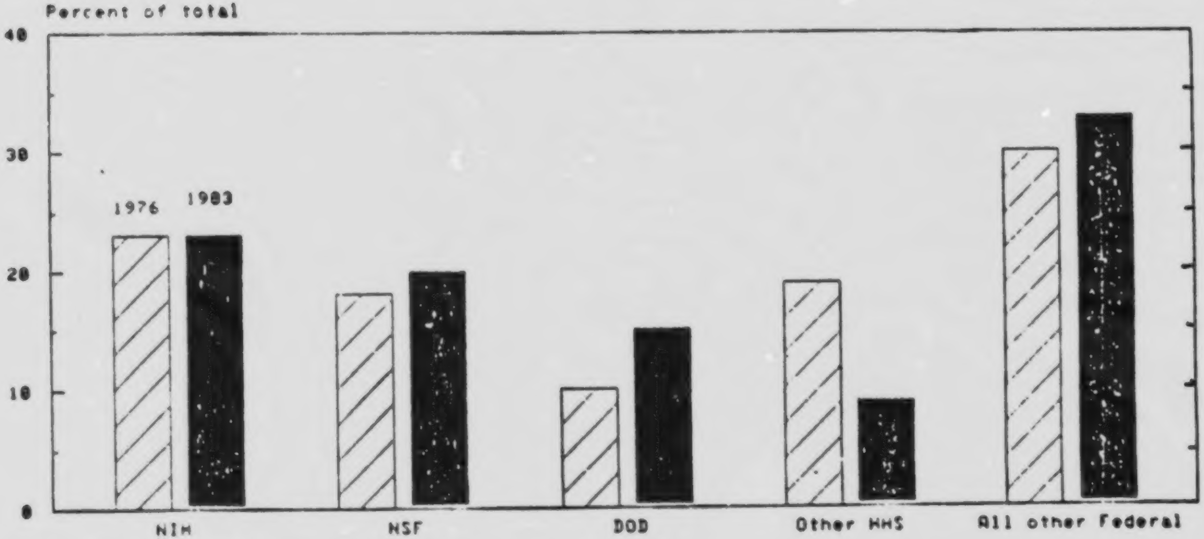
Distribution of full-time graduate science/engineering enrollment in doctorate-granting institutions by source of major support



[a] Includes support from State and local governments
SOURCE: National Science Foundation

Viewgraph #3

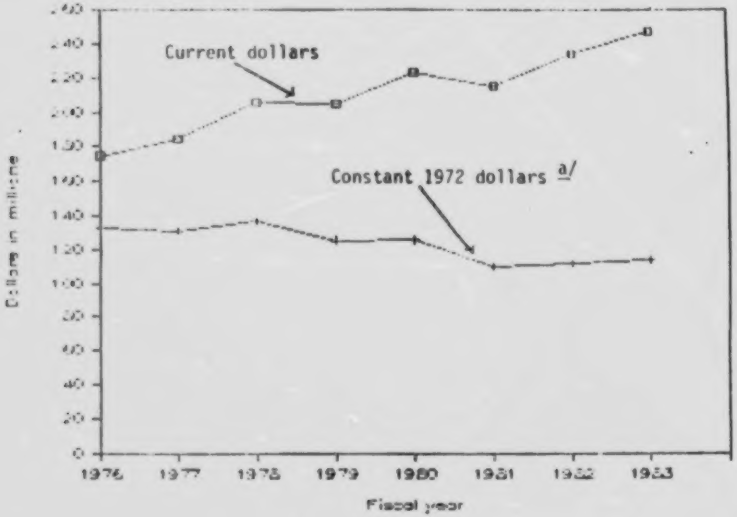
Distribution of federally supported graduate students by agency



SOURCE: National Science Foundation

Viewgraph #4

Federal obligations for fellowships, traineeships, and training grants

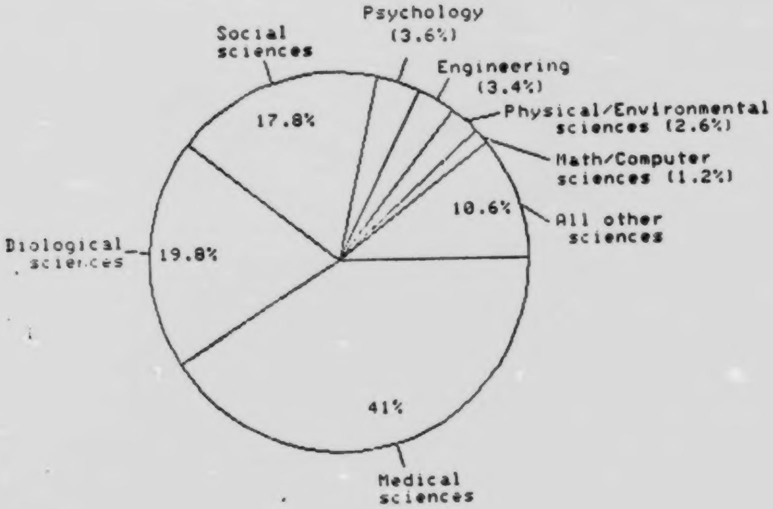


a/ Based on GNP implicit price deflator.

SOURCE: National Science Foundation

Viewgraph #5

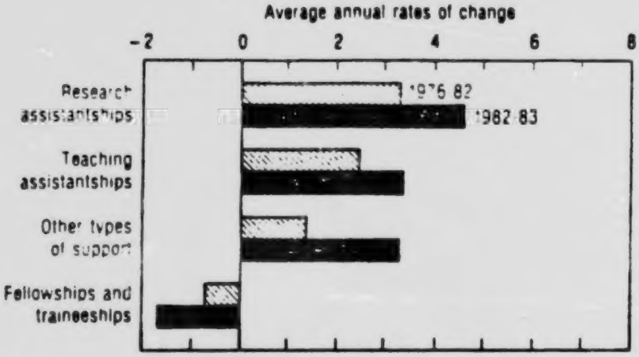
Distribution of Federal obligations for fellowships, traineeships, and training grants by field: FY 1983



SOURCE: National Science Foundation

Viewgraph #6

Full-time graduate science/engineering enrollment in doctorate-granting institutions by type of major support



SOURCE National Science Foundation

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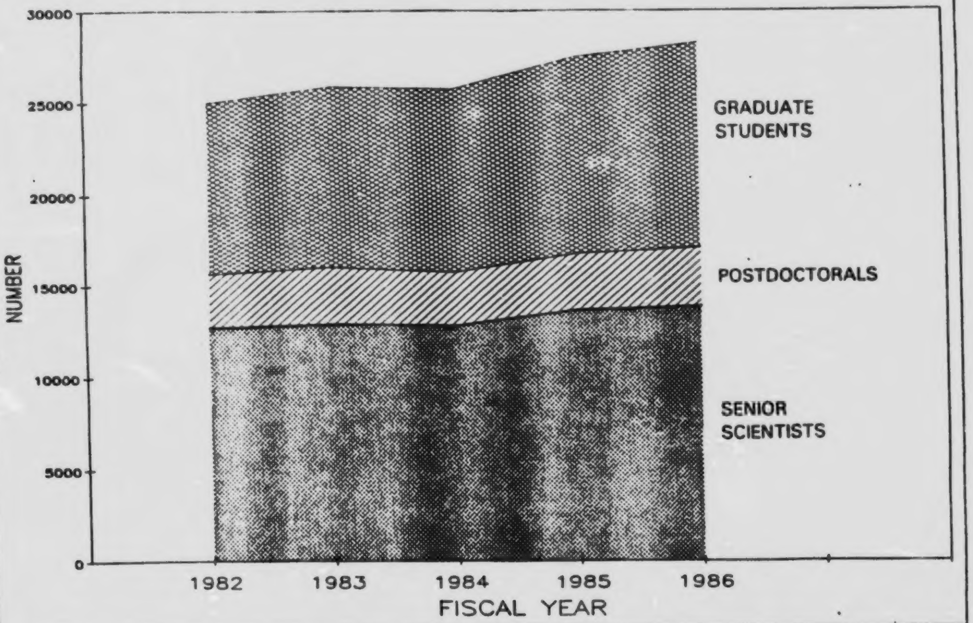
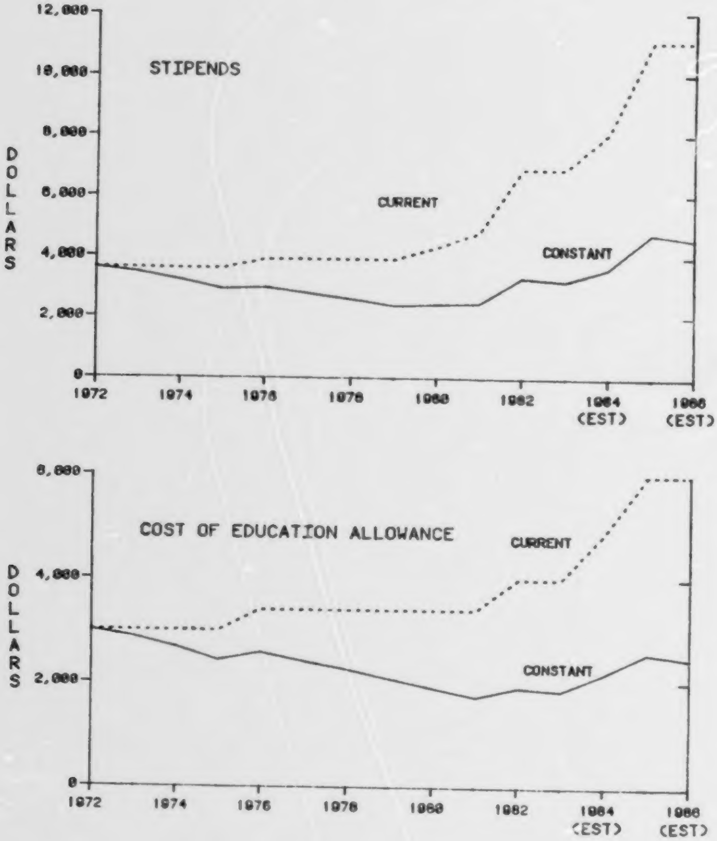
Viewgraph #7

RESEARCH GRANT PERSONNEL
FY 1982 – FY 1986



Viewgraph #8

NSF GRADUATE FELLOWSHIPS



Viewgraph #9

GROWTH RATES OF S/E DEGREES BY LEVEL AND SELECTED FIELD: 1970-82

	Bachelor's	Master's	Doctorates
		(Percent)	
Physical science	1.0	-0.6	-2.3
Engineering	3.5	1.5	-1.7
Mathematics	-6.9	-5.9	-4.8
Computer science	24.0	10.7	7.4

Source: National Center for Education Statistics and National Science Foundation

Viewgraph #10

COMPARISONS OF AVERAGE STARTING SALARIES: 1985

	B.S. Candidates	NSF Fellowship Stipend	Assistant Professors
Chemistry	21,800		22,000
Mathematics	23,900	11,100	23,000
Computer Science	24,600	Non-	27,C00
Engineering	27,000	taxable	29,000
Biological Science	17,200		22,000

Source: National Science Foundation and College and University Personnel Association

Mr. FUQUA. Thank you very much, Dr. Moore. Dr. Hill.

STATEMENT OF DR. ROBERT L. HILL, PROFESSOR AND CHAIRMAN, DEPARTMENT OF BIOCHEMISTRY, DUKE UNIVERSITY MEDICAL CENTER, DURHAM, NC

Dr. HILL. Thank you, Mr. Fuqua. I'm pleased to be here today and have an opportunity to talk to you about the support of predoctoral and postdoctoral research training, particularly training support by the NIH and ADAMHA. For the past 5 years I have served as chairman of the Committee on the National Needs for Biomedical and Behavioral Research Personnel. This committee was formed by the National Academy of Sciences in 1975 at the request of Congress, as expressed in the National Research Service Awards Act of 1974. In essence this committee was to specify the overall need for biomedical and behavioral research personnel, the subject areas in which such personnel are needed and the kinds and extent of training to be provided under national research service award programs.

Since 1975 the committee has issued seven reports; the eighth report is due out next October. The committee's reports cover the following areas in general; personnel needs; supply and demand in the clinical sciences, and in our next report this will include dental research; basic biomedical sciences; the behavioral sciences; and to some extent possible, in health services research and nursing research. Our report in October will also have a statement on a special program at the NIH called the MARC program. This is a program, the MARC is an acronym for the program, which is minority access to research careers. It currently supports some 500—about 500 students in prebaccalaureate programs around the United States with the understanding that perhaps by supporting students at this early stage in their education they will be attracted to research careers. I'll not have more to say about that, but I'd be happy to talk about it later if you wish.

Our report basically, or the statement that I have submitted to you basically contains four parts. We've described the research training system, levels of support, mechanisms of support. We've also described a comparison of the support mechanism. We've discussed briefly the sources of support and finally we have made a few comments on the evaluation of the NIH programs.

I don't want to read the complete report, but let me read a few excerpts from each of these four sections to give you some feelings about our committee's attitude toward training and some aspects of statistics about personnel.

NIH systems supports two classes of trainees for research training: predoctoral and postdoctoral. Clearly the largest predoctoral training program at NIH is for support of students in their Ph.D. It takes about 7½ years on an average for students to receive the Ph.D. degree in basic biomedical sciences. In the behavioral sciences the average is higher, something like 9 years. Clearly students engaged in full-time research and research training cannot afford very often to pay their own way through these years.

In the postdoctoral years many, many of the bioscience students get further training. Almost 70 percent of the bioscience Ph.D.'s take a post-doctoral appointment. This is quite in contrast to some of the other sciences, for example, some of the physical sciences. It's also lower in the behavioral sciences; only about 20 percent of Ph.D. graduates in the behavioral sciences, take postdoctoral training. Nevertheless, the postdoctoral training is a very important component in most biomedical science fields and seems to be increasing. Certainly, it has been so in the past decade.

In terms of mechanisms of support, Dr. Moore has already told you about programs in the NSF and some national statistics, but let me emphasize that there are basically, as far as the NIH is concerned, four kinds of training support mechanisms now in operation. First there is the training grants, second fellowships, third research assistantships, finally teacher assistantships and I could add of course a fifth, private means.

Now, training grants are awarded in national competition to institutions for individual departments or a consortium of departments. They provide trainee stipends for graduate students. They also give an institutional allowance for faculty salaries, seminars, supplies and equipment. The institution selects the trainees, either predoctoral or postdoctoral. The largest training grants—the largest investment in NIH is in the predoctoral training program. Now, the NAS committee considers training grants to be the most advantageous mechanism. It's the most meritorious universities for training are selected by peer review and there is a national competitive review. Merit is the sole criteria of training selection. Moreover, by having training programs the NIH can exercise some centralized control of the numbers of trainees in order to adjust supply and demand. And finally the trainee has some liberty within the training grant mechanism to pursue research of his own interest and not necessarily that that is tied to a particular research grant.

Fellowships, of course, are also in our view very important. They're made directly to an individual through national competition largely in the form of a stipend, mostly at the postdoctoral level. They include modest institutional allowance for supplies, equipment, many of the training grants advantages, but they do strengthen the department through continuing national review and stable support of training—of the training environment. Then there is the research assistantship. This is essentially students being paid for working on a research grant. They are certainly—this is certainly the largest source of graduate training support through the NIH. But, there is the possibility that there will be a mismatch between a trainee's objectives, that is his educational goals, and the project director's research interest maximizing research output.

And then finally there is a teacher assistantship which the NIH doesn't support, but we should recognize the teaching assistantships from funds provided by the university are a major factor in graduate training.

The NAS committee believes that all four of these major mechanisms are extremely important mechanisms of graduate student support, and I'd like to read you briefly a statement how we feel that these four mechanisms can interplay and through their interplay can lead to a very logical and good mechanism for graduate student support.

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The different forms of support, those four I've mentioned, properly administered, can be appropriately related to the various purposes and stages of the training process. For example, graduate students may be provided teaching assistantships for the third year and research assistantships, a research grant that is, for the fourth and succeeding years until the dissertation is completed and the degree awarded. This pattern allows the student to prepare as rapidly as possible for teaching and research. Teaching is postponed until the student knows enough to be able to do it well and the research assistantship is utilized at a time when the student is relatively free and well enough informed to not only make a sound choice of mentor, but to contribute substantially to the research program.

The sources of support, of course, as to how much training is given through fellowships, traineeships and so forth has been treated by Dr. Moore to a certain extent. We've included in our report, however, some statistics provided by the National Science Foundation that show some of the trends in support—sources of support for trainees. In essence, the trend has always been downward. The percentage of the number of students supported by sponsored research grants has increased somewhat, and there has been a decrease in support from the National Research Service Awards Program. The committee has recommended that the graduate students in the biosciences be supported to the extent of 10 percent of total graduate students.

In addition we feel that national research service award fellowships and traineeships should support about 40 percent of the postdoctoral pool. This has also fallen in recent years and in 1983 was 34 percent.

Finally, let me make a few comments about evaluation of the NIH training program. Our statement that I've submitted includes some summaries from three different reports conducted by the National Needs Committee. Let me just comment about the most recent report in 1984 in which we attempted to evaluate the career achievements of NIH predoctoral trainees and fellows.

This study came to the following conclusions. First, more than two-thirds of the NIH trainees and fellows supported prior to 1976 had earned doctorates compared to an estimated overall completion rate for biomedical science graduate students of less than 50 percent. NIH trainees and fellows were considerably more likely to have subsequently received NIH postdoctoral fellowships or traineeships than were members of other comparison groups. Former NIH predoctoral are also likely, more so, to become involved in NIH-sponsored activities. Those in the study group who applied for NIH research grants and have been more successful in obtaining an award than either of those in a comparison group, leading us to the general conclusion that former NIH predoctoral trainees and fellows have been more likely to pursue careers in biomedical research and have been more successful in this pursuit than their colleagues.

Thank you, Mr. Chairman, for allowing me to present some aspects of the NIH and of course I'll be happy to answer questions if there are any.

[The prepared statement of Dr. Hill follows:]

Statement of Dr. Robert L. Hill
Professor and Chairman
Department of Biochemistry
Duke University Medical Center

Prepared for the Task Force on Science Policy
House Committee on Science and Technology

July 10, 1985

I am happy to have this opportunity to speak to you today on the mechanisms used at present for support of predoctoral and postdoctoral research training, with special emphasis on training support by the NIH/ADAMHA.

For the past 5 years I have served as chairman of the Committee on National Needs for Biomedical and Behavioral Research Personnel. This Committee was formed by the National Academy of Sciences (NAS) in 1975 at the request of Congress as expressed in the National Research Service Awards Act of 1974 (NRSA). That legislation addressed the questions of determining appropriate levels of federal support for research training and the fields in which personnel will be needed. Answers to these questions were to be derived from a continuing, comprehensive study, which, according to the statute, would be conducted by the NAS. In this connection, training could be provided only in those subject areas for which "there is a need for personnel", as determined by the NAS.

As part of this broad-ranging study over the past 10 years, the NAS Committee has also responded to another Congressional directive... i.e., "to identify the kinds of research positions available to and held by individuals completing [federally supported] training." A recent publication, as well as a forthcoming report, examines the extent to which those individuals who had received predoctoral and postdoctoral support from NIH research training programs have been successful in pursuing careers in biomedical research. The evidence indicates that these programs have been effective in attracting talented students to research careers, setting high standards for research training by relying on peer review of applications, and strengthening the capability of institutions to offer quality training.

The NAS Committee has responded to its charge by producing seven major reports since 1975, with an eighth scheduled for publication in October, 1985. Copies have been distributed to congressional committees, the Secretary of HHS, federal agencies, and the scientific community.

Frequent reference to the NAS Committee's findings and recommendations during appropriation hearings, inquiries from Congressional staff, and reactions at Committee-sponsored public meetings suggest that these reports and the data compiled for this study have been useful.

A complex system has evolved in this country for training biomedical and behavioral scientists. The NAS Committee has described the system quite well in its past reports and I draw heavily on that material in presenting the following overview of the system.

THE RESEARCH TRAINING SYSTEM IN THE BIOMEDICAL AND BEHAVIORAL SCIENCES

Formal research training in the biomedical and behavioral sciences is essentially a postbaccalaureate activity in the United States. The settings in which training occurs include university graduate schools; schools of medicine, dentistry, veterinary science, public health, and engineering and associated laboratories, hospitals, mental health clinics, counseling centers, social agencies, and other field areas.

In terms of their level, training programs may be divided into two broad classes--predoctoral and postdoctoral. Predoctoral programs are aimed principally at individuals who are seeking a research doctorate defined as the Ph.D. or equivalent. Postdoctoral training is provided for individuals who hold either a research doctorate or a health-related professional doctorate such as M.D., D.D.S., or D.V.M.

Levels of Training

Financial support for pre- and postdoctoral research training comes from five principal sources: individual fellowships, institutional training grants, research assistantships, teaching assistantships and private means. The NRSA Act, which repealed all previous training authorities of NIH/ADAMHA, provides authority for awarding of individual fellowships and so-called "institutional" fellowships which are indistinguishable from the research training grants administered by NIH since around 1950. Individual fellowships from NIH are primarily for postdoctoral training whereas NIH training grants support both pre- and postdoctoral trainees. Numerous research assistants at pre- and postdoctoral levels are also supported by research grants. Their compensation, however, is for services rendered to the research project. Although these mechanisms are the primary means for support of training from NIH funds, support for predoctoral training also comes from teaching assistantships provided in return for contributions to teaching programs, most notably at universities with large prebaccalaureate student teaching loads.

Predoctoral. Predoctoral training is generally carried on within the context of a specific scientific discipline, such as anatomy, biochemistry, microbiology, or psychology. The functional unit of predoctoral training is the disciplinary department or, in some instances, a structured multidisciplinary program which may cross departmental lines.

The predoctoral student characteristically progresses through a series of didactic and laboratory courses; learns to communicate in small seminar groups; and, through continuing interactions with peers, postdoctoral fellows, the faculty, and visiting lecturers, gradually acquires the traditions, style, and research methodology of the particular discipline. It is common practice in the biomedical sciences for the graduate student to conduct one phase of a large research program in the faculty mentor's laboratory, where he or she works as a member of a research group, utilizing all the research facilities in the laboratory and conferring frequently with mentor and colleagues. The average duration of graduate training in the basic biomedical sciences is 7.5 years from enrollment in graduate school to receipt of the Ph.D degree, and about 9 years in behavioral fields.

Less formal predoctoral research training programs are available to individuals who are pursuing a health professions doctorate, primarily medical students who are taking time out for research training. These are selected individuals who, having shown interest in the biologic phenomena underlying health and disease, have been encouraged to develop their research potential. Their research training may be carried on part-time and concurrently with their regular studies, or full-time during an "off" quarter or during a year's release from medical training.

Postdoctoral. The value of postdoctoral training, both at the post-Ph.D. and postprofessional levels, has perhaps been most widely recognized in the biomedical sciences. In addition, postdoctoral training has become almost a requirement for the physician or dentist wishing to pursue a research career in academic medicine. The opportunity for M.D. and Ph.D. graduates to be trained together during the postdoctoral period is widely regarded as a valuable aspect of this experience. Postdoctoral education is also regarded as important for training Ph.D.s from the physical sciences, who wish to utilize their special knowledge and capabilities for biomedical and behavioral research.

Post-Ph.D. training is oriented toward specialized experience in a research topic rather than a discipline. Each year an increasing proportion of those who receive the Ph.D. degree have been going on to postdoctoral training to sharpen their research skills under outstanding mentors. In biochemistry, for example, the percentage of Ph.D. recipients with definite plans for postdoctoral study rose from 60.2 to 69.2 over the period 1973-83. A large percentage of these Ph.D. holders seek such experience in settings other than those of their graduate school mentors in order to gain new perspectives and to respond to new opportunities, particularly in interdisciplinary and emerging research areas.

Research training for individuals holding a health professions doctorate (M.D., D.V.M., D.D.S.) must take into account the difference between their educational background and that of the the post-Ph.D. Medical school curricula and subsequent years of residency training were designed to produce clinicians and not medical scientists. Thus residents who then elect to become clinical scientists require further scientific training. They need, in fact, to start over at the bottom of a second and new career.

Programs suitable for that purpose should generally be multidepartmental, have organized academic content, and provide substantial opportunity for conduct of a research project under competent direction. Two or perhaps three years are required in most cases to include the course work, seminar participation, and research necessary to produce a fledgling clinical investigator.

Various mechanisms have been developed for the specialized training of M.D. researchers. One such mechanism is the NIH-sponsored Medical Scientist Training Program (MSTP) which supports an integrated medical and graduate science course of study leading to the combined M.D./Ph.D. degree. Combined degree programs incorporate economies of teaching by eliminating duplication between the medical and graduate curricula, and by emphasizing relations between otherwise separated subject matter. With strength in both basic medical science and clinical medicine, MSTP graduates are able to bring to a basic science department a point of view which, on the one hand, facilitates relating their research to clinical problems, and on the other hand permits exploration in depth of selected medical problems encountered initially at the bedside.

Mechanisms of Support

The pluralistic system (fellowships, training grants, research assistantships, teaching assistantships, and private means) of financial support for individuals engaged in research training includes both private and public support. All types of support are used by most major research training centers and an individual may use more than one means of support before completing training. While more administratively cumbersome than a single source, the pluralistic system is believed to have provided greater flexibility to the institutions, the departments involved in the training, and the trainees.

Individual Fellowships. These are awards made directly to the individual, largely in the form of a stipend and tuition. Fellowships come from a variety of sources, such as the federal government, voluntary health organizations, foundations, and universities. Fellowships have been used for many years as a means of encouraging excellence and reducing financial barriers to training. Except for local programs, the fellowship may be used at any host institution with appropriate facilities and where a suitable mentor is willing to supervise the training. National fellowship programs permit utilization of a more uniform set of standards in the selection of fellows, and the awardee has wider latitude in the selection of a training site. The award, as in the case of NIH/ADAMHA fellowships, may include a modest institutional allowance to help defray costs of training the fellow such as tuition and fees, research supplies, equipment, travel to scientific meetings, and related items. That allowance differs, however, from funds included in training grants for the specific purpose of strengthening the scientific milieu of the department in which the training is pursued.

Training grants. These grants are awarded by the federal government to institutions for individual departments or a consortium of departments. In addition to providing trainee stipends and tuition, these grants enhance the quality of training by providing funds to departments for salaries, special seminars, courses, supplies, and equipment. In contrast to departmental training grants, multi-disciplinary grants make it easier for graduate students to anticipate emerging scientific fields and to select their dissertation topics accordingly, with access to appropriate faculty in related subject areas across departmental lines. Programs supported by these grants may be devoted exclusively to either predoctoral or postdoctoral training levels, or both. Individual trainees are selected by faculty participants on the basis of credentials and letters of recommendation similar to those in fellowship programs. The grants are awarded through national competition, with continuing peer review to ensure that training is conducted in departments of the highest quality.

Research assistantships. Many graduate students and postdoctorals receive support for work performed on research projects. Often this work fits their scientific interests and training requirements and hence serves as useful educational experience. The student conducts original research as part of the overall project; it is not only suitable for a dissertation but also contributes to the advance of research supported by the project grant.

Teaching assistantships. Graduate students and postdoctorals may be supported by their institutions as teaching assistants because of their contributions to teaching programs. These teaching assignments are usually at the undergraduate level, and, hence, opportunities for this type of support tend to be available only in institutions and departments with large undergraduate teaching responsibilities. The teaching assistant typically grades papers, sets up experiments for laboratory sessions, holds classes in which lectures given by senior faculty members are discussed and in which texts and other written material relating to the course are reviewed, and guides students in laboratory work associated with undergraduate courses. These duties commonly occupy one-half of the teaching assistant's time, in return for which a modest stipend is provided and tuition fees are remitted. Valuable experience is acquired in the art of teaching, which for most Ph.D. holders is an essential part of their future jobs.

Private means. Many students, particularly at the predoctoral level, support their training through private resources, including family aid, private loans, part-time employment, and assistance from a working spouse.

COMPARISON OF TRAINING SUPPORT MECHANISMS

The NAS Committee considers the training grant to be one of the best training mechanisms. It permits selection of those departments most competent to conduct research training, as judged by competitive national peer review. It minimizes financial disincentives to training so that merit remains the sole criterion in trainee selection. Moreover, trainees can engage in research topics of their own choosing and are not required to pursue research directly related to a preceptor's own research support. By providing funds for special seminars, courses, supplies, and equipment, the training grant also creates a unique environment for learning.

Fellowships, which are awarded directly to the recipient, have many of the same advantages, but do not strengthen the department(s) through the process of continual national review and stable support of the training environment. The current system under NRSA, which incorporates a mix of these two mechanisms, allows for a greater flexibility than would prevail though exclusive reliance on either instrument alone.

Support for predoctoral training by research grants is less desirable in the initial years of Ph.D. study than support by individual fellowships, training grants or teaching assistantships. The student supported by a grant is employed for services rendered rather than supported to achieve an educational objective. Thus, the time required for laboratory work may be taken from that needed for course work. If sufficient time is given to course work, the expected laboratory work may suffer. Of course, once a Ph.D. student has completed all educational requirements for the Ph.D. except completion of thesis research and defense of thesis, the research grant is an excellent means for support or predoctoral training. Indeed, predoctoral students on a research grant cost less than postdoctorals and they often produce as much research results. Support from research grants for postdoctoral training is not as flexible for the trainees as individual fellowships and training grants since the trainee's research project is necessarily defined by the principal investigator of the grant. Nevertheless, the postdoctoral fellow supported by the research grant usually chooses further training in the area of the principal investigator, and the grant mechanism in such a case is highly appropriate. In spite of a few deficiencies, the research grant will likely remain a major mechanism of research training in the future.

Where training is pursued in changing or emerging scientific areas, teaching assistantships may not be available. Also, they are frequently not available for graduate students in fields where teaching of undergraduates is not a major academic activity, as for example, in the basic biomedical sciences in privately controlled medical schools.

The role of private means is limited, inasmuch as graduate education is a lengthy and expensive process. Excessive reliance on this type of support is undesirable, because many persons of superior potential cannot afford to undertake research training.

These different forms of support, properly administered, can be appropriately related to the various purposes and stages of the training process. For example, graduate students may be provided with fellowships or traineeships for the first 2 years, teaching assistantships for the third year, and research assistantships for the fourth and succeeding years until the dissertation is completed and the degree awarded. This pattern allows the student to prepare as rapidly as possible for teaching and research. Teaching is postponed until the student knows enough to be able to do it well, and the research assistantship is utilized at a time when the student is relatively free and well enough informed to make a sound choice of mentor whose research program has an appropriate opening. Under its auspices and support, the student can conduct the research needed for the dissertation while contributing to the mentor's research program.

SOURCES OF SUPPORT

The National Science Foundation compiles aggregate data on sources of support for graduate education in the U.S. Some data extracted from NSF's most recent reports are presented in the following tables.

Table 1 shows the sources of predoctoral support for graduate students in the biological and clinical science fields between 1979 and 1983. During that period, the number of bioscience students supported by traineeships or fellowships declined from almost 14% to 12%, while the number supported on federally sponsored research grants increased from over 13% to over 14%. As noted in the footnote to Table 1, the precentage of bioscience graduate students supported under NRSA programs fell below 10% in 1981 and 1983. The NAS committee has recommended that this percentage be maintained at about 10% of bioscience graduate students.

For most bioscience postdoctoral trainees, federally sponsored research grants have also become the largest source of support (see Table 2), with over 40% of all bioscience postdoctorates supported by this means. In 1979, NRSA fellowships and traineeships supported about 42% of bioscience postdoctorates. This percentage has declined to about 34% in 1983. The NAS committee has recommended that the NRSA share be maintained at about 40%.

In the clinical sciences, NRSA traineeships and fellowships are the dominant support mechanism for postdoctorates, most of whom are physicians, dentists or veterinarians seeking research training. But that support has also declined from 50% of all clinical science postdoctorates in 1979 to 45% in 1983. The NAS recommends that this be increased to about 60% in the late 1980's.

EVALUATION OF NIH TRAINING PROGRAMS

A number of follow-up studies conducted by the NAS Committee and others have evaluated the effectiveness of the NIH programs in attracting students to research careers. By ascertaining what career patterns the former trainees have followed and how productive they have been, these studies have concluded that the training mechanisms are having the intended effect of ensuring the availability of well-trained scientists to carry out the government's research agenda. Here are some findings from those studies:

TABLE 1 Graduate Students in Biological and Clinical Science Fields, by Mechanism and Source of Support, 1979-1983

		Total Graduate Students	Mechanism of Support							
			Federal				Non-Federal			
			Total	Traineeships & Fellowships[a]	Research Assistantships	Other	Total	Traineeships & Fellowships	Research Assistantships	Other
Biological Sciences										
1979	#	32,218	11,084	5,239	5,116	729	27,134	3,099	4,395	19,640
	%	100.0	29.0	13.7	13.4	1.9	71.0	8.1	11.5	51.4
1981	#	37,582	10,757	4,691	5,478	588	26,825	3,387	4,661	18,777
	%	100.0	28.6	12.5	14.6	1.6	71.4	9.0	12.4	50.0
1983	#	37,186	10,391	4,459	5,361	571	26,795	3,573	4,957	18,265
	%	100.0	27.9	12.0	14.4	1.5	72.1	9.6	13.3	49.1
Clinical Sciences										
1979	#	23,138	8,373	7,019	634	720	14,765	1,388	827	12,550
	%	100.0	36.2	30.3	2.7	3.1	63.8	6.0	3.6	54.2
1981	#	24,583	7,987	6,491	649	847	16,596	1,515	917	14,164
	%	100.0	32.5	26.4	2.6	3.4	67.5	6.2	3.7	57.6
1983	#	23,183	5,762	4,572	624	566	17,421	1,709	1,090	14,622
	%	100.0	24.9	19.7	2.7	2.4	75.1	7.4	4.7	63.1

[a] The number of traineeships and fellowships by the NIH and ADAMHA in 1979, 1981, and 1983 respectively was: 4,101 (10.7%), 3,708 (9.9%), 3,467 (9.3%).

Source: National Science Foundation. Academic Science/Engineering: Graduate Enrollment and Support, fall 1983.

TABLE 2 Postdoctoral Trainees in the Biological and Clinical Sciences, by Mechanism and Source of Support, 1979-1983

		Total Postdoctorates	Mechanism of Support			
			Federal			Non-Federal[a]
			Total	Traineeships & Fellowships[b]	Research Assistantships	
Biological Sciences						
1979	#	7,711	6,370	3,255	3,115	1,341
	%	100.0	82.6	42.2	40.4	17.4
1981	#	8,287	6,549	2,774	3,775	1,738
	%	100.0	79.0	33.5	45.5	21.0
1983	#	9,269	7,184	3,146	4,038	2,085
	%	100.0	77.5	33.9	43.6	22.5
Clinical Sciences						
1979	#	5,511	3,699	2,757	942	1,812
	%	100.0	67.1	50.0	17.1	32.9
1981	#	5,904	3,970	2,932	1,038	1,934
	%	100.0	67.2	49.7	17.6	32.8
1983	#	5,484	3,487	2,481	1,006	1,997
	%	100.0	63.6	45.2	18.3	36.4

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[a] NSF data on non-federal sources of support for postdoctorates are not broken out by mechanism. It is assumed that these are primarily fellowships and research assistantships.

[b] The NSF data on federal traineeships and fellowships are less than those reported by NIH and ADAMHA. The latter are shown in this table.

Source: National Science Foundation. Academic Science: Graduate Enrollment and Support, 1979-83.
NIH and ADAMHA data are from reports made by those agencies to the NAS Committee on National Needs for Biomedical and Behavioral Research Personnel.

A. From Research Taining & Career Patterns of Bioscientists National Research Council, 1975.

1. In the biological sciences, those individuals with predoctoral traineeships or fellowships attained the Ph.D. more frequently and in less time than those without such support. Differences in ability, however, may account for some of the differences in Ph.D. attainment rates and in the shorter time lapse from B.A. to Ph.D.

2. The more education and training scientists receive, the more likely they are to be engaged primarily in research activities, to be employed by a university or professional school, and to have greater research productivity as measured by the number of publications and citations in the scientific literature. These observations seem to result from the interaction that takes place between the commitment to research and the training received, the one perhaps complementing the others. The association between the level of education and training on the one hand and level of research activity on the other is a consistent one which holds for M.D.s as well as Ph.D.s and persists throughout most stages of a career.

3. For M.D.s, the attainment of the Ph.D. degree is an important factor in career outcomes. Only 20 percent of the M.D.s with NIH post-M.D. support but no Ph.D. were engaged primarily in research in 1968-70, whereas almost 50 percent of those with NIH post-M.D. support and the Ph.D. were so engaged.

B. From Personnel Needs and Training for Biomedical and Behavioral Research Personnel, National Research Council, 1981.

A recent study by the AAMC compared the career outcomes of four specific programs for research training of physicians:
   a. postdoctoral traineeships and fellowships
   b. medical scientist training program (MD-Ph.D)
   c. research associates at NIH
   d. clinical associates at NIH

The comparison revealed that:

1. All four programs were highly successful in producing physician investigators. MSTP had the highest proportion of graduates--74 percent--who could be confirmed as currently involved in research. Comparable figures for Research Associates, Clinical Associates, and Trainees/Fellows were 58 percent, 58 percent and 47 percent, respectively. When program graduates engaged in other medical school faculty activity are included, the percentages rise to 89 percent, 75 percent, 63 percent, and 62 percent, respectively. As a

percent of graduates with known current career status, 94 percent of MSTP and 95 percent of Research Associates were in research and teaching. Comparable percentages for Clinical Associates and Trainees/Fellows were 86 percent and 83 percent, respectively.

2. Research grant success rates at NIH did not appear to discriminate among the four groups. MSTP graduates, Clinical Associates, and Trainees/Fellows had higher approval rates and better average priority scores than those for all applicants. Judged by only a small number of applications, the performance of former Research Associates was mixed--relatively low approval rate but excellent average priority scores for approved applications.

3. Publication performance for graduates of the four training programs showed marked differences in the quantity and scientific depth of the articles they published. MSTP graduate students were the most prolific authors, having published 995 articles by 1981, compared with 716 articles by Research Associates, 673 by Clinical Associates, and 408 by Trainees/Fellows. MSTP graduates and Reseach Associates published predominantly in journals characterized by a high degree of scientific rigor, e.g., Journal of Biological Chemistry and American Journal of Physiology. Former Clinical Associates and Trainees/Fellows published most frequently in journals, such as the New England Journal of Medicine, which contain a mixture of reports on clinical investigation and clinical observation. Of the four groups of trainees, former Clinical Associates published most frequently in journals emphasizing clinical observation, e.g., the Journal of the American Medical Association.

C. From The Career Achievements of NIH Predoctoral Trainees and Fellows. Institute of Medicine, 1984.

The study results indicate that former NIH predoctorals have outperformed members of the two comparison groups, in terms of a diverse set of career outcome measures. Among the key findings are the following:

- By FY1981, more than two-thirds of the NIH trainees and fellows supported prior to FY1976 had earned doctorates, compared with an estimated overall completion rate for biomedical science graduate students of less than 50 percent.
- NIH trainees and fellows were considerably more likely to have subsequently received NIH postdoctoral fellowships or traineeships than were members of either comparison group.
- Former NIH predoctorals were also more likely to become involved (at later stages in their careers) in NIH-sponsored activities.
- In comparison with Groups I and II, an appreciably larger fraction of the study group applied for NIH research grants.

- Those in the study group who applied for NIH research grants have been more successful in obtaining awards than have those in either comparison group.
- Former NIH trainees and fellows have authored, on the average, more articles than have their biomedical science colleagues.
- Articles written by members of the study group have typically received more citations in the bioscience literature.

Although the observed differences among the three groups are not necessarily large, the findings are remarkably consistent for the numerous indices examined--leading to the overall conclusion that former NIH predoctoral trainees and fellows have been more likely to pursue careers in biomedical research and have been more successful in this pursuit than their colleagues. That does not necessarily mean, however, that these same students might not have done just as well had NIH predoctoral support not been available to them. Since the NIH awards have been made on the basis of criteria directly and indirectly related to the recipients' abilities and interest in biomedical research, it cannot be determined whether their superior records of achievement may be attributed to the selection process, the training they received, or a combination of these and other factors. Nevertheless, one may conclude from the study findings that graduates of the NIH predoctoral training programs have been highly successful in pursuing careers in biomedical research.

These follow-up studies of former NIH trainees and fellows have generated evidence that the research training programs have been effective in attracting talented students to research careers, setting high standards for research training, and strengthening the capability of institutions to offer a high quality training environment.

RESEARCH TRAINING AND RESEARCH CAREER LONGEVITY

Follow-up studies such as the above suggest that participation in formal research training programs enhances the trainees' subsequent research productivity. Proof of this proposition is hard to obtain because there are many factors, obvious and subtle, that could also affect an individual's productivity. Since measuring their separate effects is extremely difficult, it is necessary to rely instead on certain measurable relationships that give evidence for or against the proposition.

One such link is that between the duration of research grant support and previous research training experience. Recently developed data presented in Table 3 show that those scientists with NIH-supported postdoctoral training survived much longer in the competition for NIH research grants than those without such postdoctoral training. Ph.D. scientists, it should be noted, exhibit a similar pattern. Furthermore, the difference is consistent over the period of years shown. To the extent that survival time as a principal investigator is an acceptable measure of research productivity, these data clearly imply that postdoctoral research training is an important factor in subsequent research success.

TABLE 3 Length of Career as NIH Principal Investigator With and Without NIH Postdoctoral Training

Fiscal Year of First Research (R01) Award		With NIH Postdoctoral Training		No NIH-Supported Postdoctoral Training	
	M.D.'s	Ph.D's	M.D.'s	Ph.D's	M.D.'s
1957	Yrs. as NIH P.I. (median)	16.8	16.7	11.8	10.8
	No. of P.I.'s	76	135	447	515
1958	Yrs. as NIH P.I. (median)	20.5	17.8	10.1	11.7
	No. of P.I.'s	46	97	276	321
1959	Yrs. as NIH P.I. (median)	16.5	13.5	10.4	8.7
	No. of P.I.'s	88	134	418	565
1960	Yrs. as NIH P.I. (median)	10.3	12.8	7.9	6.9
	No. of P.I.'s	120	162	467	568
1961	Yrs. as NIH P.I. (median)	11.6	11.7	6.9	5.8
	No. of P.I.'s	101	143	343	497
1962	Yrs. as NIH P.I. (median)	9.8	10.4	6.7	5.9
	No. of P.I.'s	159	174	351	508
1963	Yrs. as NIH P.I. (median)	10.7	11.2	5.7	5.4
	No. of P.I.'s	160	215	290	455

SOURCE: National Research Council (1958-80, 1974-81, 1979a, special tabulation 5/19/81).

Mr. **Fuqua**. Thank you very much, Dr. Hill.

Dr. Ver Steeg, we'll hear from you.

STATEMENT OF DR. CLARENCE L. VER STEEG, DEAN OF THE GRADUATE SCHOOL, NORTHWESTERN UNIVERSITY, EVANSTON, IL

Dr. **Ver Steeg**. Thank you very much for letting me be a part of this panel. I'm president of the Association for Graduate Schools and my testimony—written testimony is rather long, but I have abridged it and there is a copy——

Mr. **Fuqua**. We will make the written part, the longer part, part of the record.

Dr. **Ver Steeg**. Thank you very much. For those in fact in the audience I will in fact call out the pages so that they can follow.

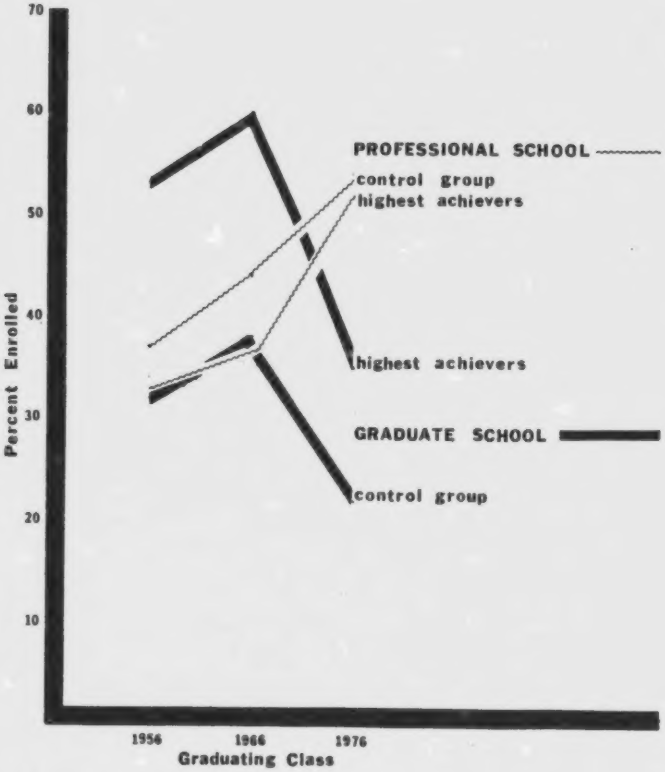
The first thing I—there are about five or six things I wish to cover. One is postgraduate choices of undergraduate highest achievers. Second, the overall graduate student funding by source at Northwestern. Third, the funding mechanisms for technology at Northwestern. Fourth, the funding mechanisms for science and nonscience and I was asked to particularly emphasize nonscience at Northwestern; the funding mechanisms for international students at Northwestern; and then loans as a funding mechanisms; and then a few things about summary.

Obviously my testimony, therefore, is directed avoid rhetoric and stick pretty much to those details. The material, in fact, gives dollar amounts, actual dollar amounts that are used by Northwestern, by me, and therefore they are very specific.

If you look at figure 1, which is page 7 of the written testimony, it indicates that the postbaccalaureate choices of highest achievers took a very decided decline between 1966 and 1976 and indeed, in contrast, the number of highest achievers who attended professional schools increased substantially and eclipsed, in fact, the number of highest achievers who are going to graduate schools. That was on page 7 of the written testimony.

FIGURE 1

Post-Baccalaureate Enrollment
Classes of 1956, 1966, and 1976

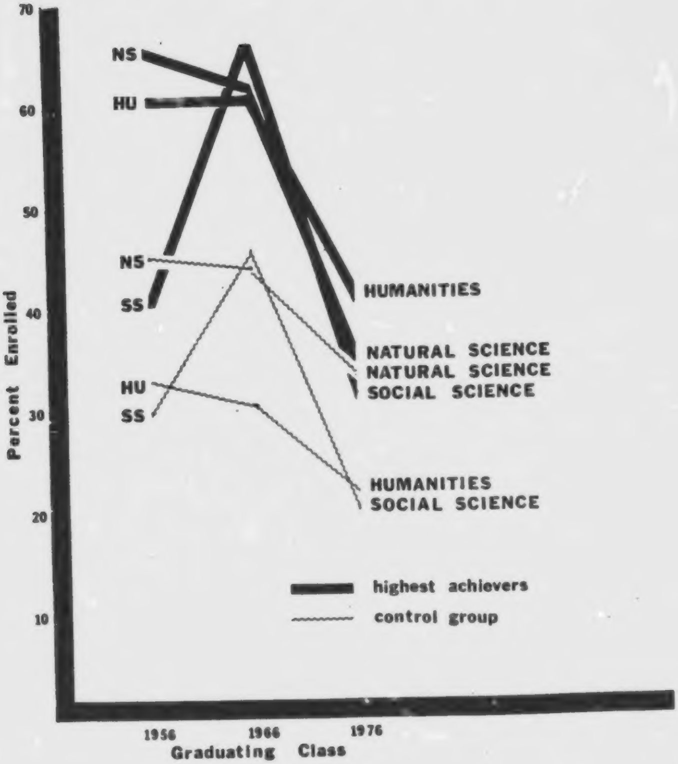


On the—the interesting part of this is that it doesn't discriminate between humanities and the sciences or sciences and nonsciences. Figure two, in other words, indicates that this decline was just as precipitous for the natural sciences as it was for the humanities. And this is substantiated by statistical material, which is in the study of highest achievers, which has been published. And this study conducted by Northwestern.

FIGURE 2

GRADUATE SCHOOL ENROLLMENT
Classes of 1956, 1966, and 1976

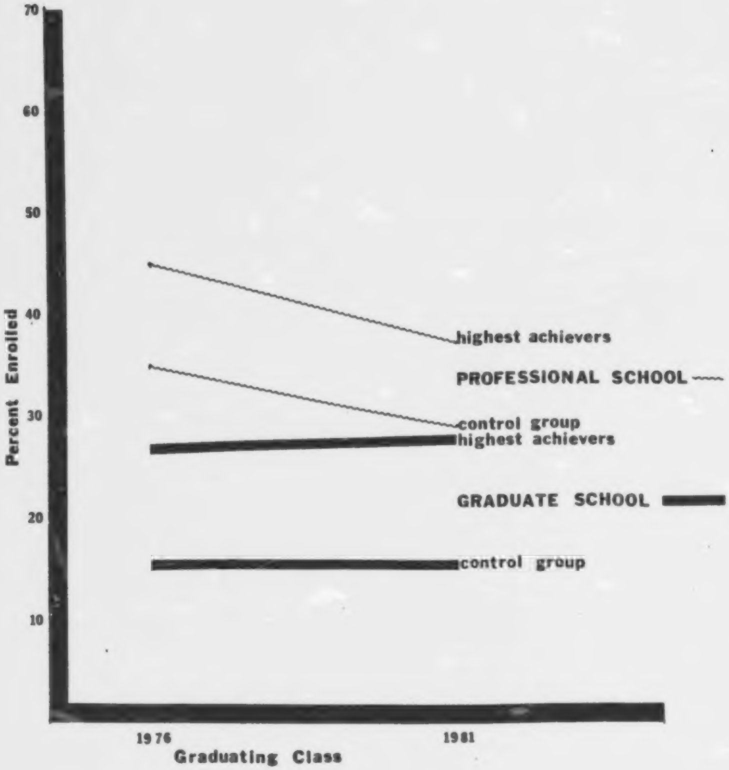
By Undergraduate Major



Beginning in figure 5 page 11, there was a certain stabilization that occurred. We don't know if it is permanent or whether in fact it is temporary, but in that case the number of highest achievers who were attending graduate school pretty much stabilized, attending professional schools tended to decline. That decline being largely, in fact, responsible by a decline in male enrollment, though the other charts that you see are characteristic of both male and female.

FIGURE 5

**Post-Baccalaureate Enrollment
Within Two Years of Graduation
Classes of 1976 and 1981**

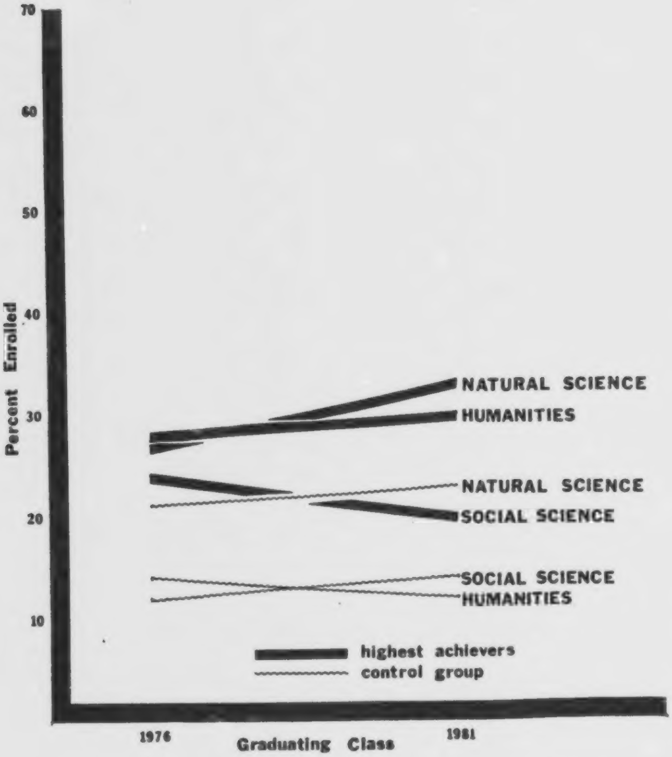


The chart 6 on page 12 as a matter of fact, indicates that this tendency of a stabilization occurred throughout the various academic areas with perhaps a slight edge to natural science and a slight decline in social science. Whether that is statistically important is in fact debatable.

FIGURE 6

GRADUATE SCHOOL ENROLLMENT
Within Two Years of Graduation
Classes of 1976 and 1981

By Undergraduate Major



Going from there to the specifics of funding of graduate students through various mechanisms at Northwestern University, which is on page 21 of the written testimony, I have used 1976, 1977, 1980, 1981 and 1984, 1985. There are three major areas in which I've divided this. Grant support, which means in effect, support that comes without any service. Service required to support, things like TA's, RA's, and so on. And self-support. In some respects the service required support could be, in fact, designated as self-support because everyone performs a service in exchange for some compensation. If you look at that over the period of years, and let me first look at the university appropriated funds under grant support, that remains relatively constant with some general decline on fellowships and scholorships from 15.3 percent to 14.2 percent. Nonuniversity funds, and that decline has been from 1976–80, 50-percent decline with some rise from 1980–81, but still in 1980–81 the decline is 28 percent below the 1976 level. If you look at why that decline occurred it conforms, to an extent, with my two colleagues who preceded me, there was a 77 percent decline in traineeships, which has been a very fundamental change that has changed the whole character, in fact, of funding. Government fellowships took a dip and then came back, which again conforms to the National trend and if you look at the U.S. private and corporate fellowships they also declined about 50 percent. This is something of a surprise, but it conforms a little bit to some of the problems that corporate world has had, in fact, in the ups and downs of the economy.

NORTHWESTERN UNIVERSITY
The Graduate School

GRADUATE STUDENT FUNDING BY SOURCE
Comparison among Fall Quarters 1976/77, 1980/1981 and 1984/85

	Percent of Total Support*		
	1976/77	1980/81	1984/85
GRANT SUPPORT			
University Appropriated Funds	15.3	13.9	14.2
Fellowships	10.3	10.8	10.5
Scholarships	5.0	3.1	3.7
Non-University Appropriated Funds	11.9	6.5	8.5
Endowed Fellowships	**	.9	.9
Government Fellowships	1.6	.8	1.5
Government Traineeships	5.3	2.1	1.2
U.S. Private/Corporate Fellowships	4.6	.5	2.2
Foreign Private/Government Fellowships	**	1.1	2.2
Outside Graduate Fellowships	.4	1.1	.5
SERVICE REQUIRED SUPPORT			
University Funds for Service	19.7	17.8	21.9
GRAT/S ***	-0-	3.5	4.4
TA: Appropriated Funds	19.7	13.3	16.7
TA: Work/Study Matching Funds	-0-	1.0	.8
Non-University Appropriated Funds for Service	11.0	17.1	15.2
Departmental Sources	**	3.2	2.8
TA: Work/Study Federal Portion	-0-	4.1	1.8
RA: Government	10.6	8.4	8.8
RA: Private	.4	.9	.8
Continuing Education	**	.5	1.0
SELF SUPPORT			
Loans	7.4	8.1	5.7
Personal Funds - tuition & non-tuition	34.7	36.1	34.3
Other	-0-	.5	.2
TOTAL	100.0	100.0	100.0

*These columns show the percent of total support of all full-time students from a particular source. The total support amount is derived by multiplying the student budget for maintenance and tuition by the full-time enrollment. The tuition figure is prorated to reflect the reduced tuition rates when appropriate.

** The 1976/77 Financial Aid Survey did not account for these data.

*** GRAT/S stands for Graduate Research Assistant Tuition Scholarship

7/2/85

If you look at the service required support you will notice that it goes from 19.7 percent to 21.9, 11 percent increase, which means, in fact, that the university is supplying more dollars. Part of that, I must say, comes from what we call GRATS, which is an acronym for graduate research assistance tuition scholarship and this refers to those principal investigators who have received Federal grants and they found that they were not in competition with other institutions because of the problem of tuition in a private institution. So, what it amounts to is that the university has developed a policy to provide the principal investigator with a scholarship for a student who, in fact, is serving as a research assistant on a funding project from the Federal Government.

The RA's under nonuniversity support have declined, at least at Northwestern, about a 17-percent decline over a period from 1976–84.

Then looking at a little more breakdown in page 22 of the written testimony, the funding mechanisms for the technological institute, in other words engineering. If you look at the whole you will discover that the university funds represent 49 percent of the funding source for students—this is only for the fall quarter, I might add, and therefore, if you want to get an annual you have to multiply all those dollars by four—whereas the nonuniversity funds were about 51 percent. Take away the 18 percent that are personal funds or loans, that amounts to the nonuniversity funds that are approximately 33 percent. Of that nonuniversity funds, some 20 percent are federally supported. That is small work study fund, small amount in Government—large amounts in Government fellowships, but particularly on the research assistant Government grants, the project grants.

I'll be very happy to answer additional questions with regard to this, but that will at least give you a feeling. I have a breakdown in the written testimony by department and I won't go into that, but it indicates pretty clearly that there are certain departments that are very dependent upon Federal sources: Chemical engineering, mechanical engineering, civil engineering, computer sciences, interestingly enough, not quite as much. There is a change in policy, for example, in chemical engineering. We have a very difficult time because the national priorities have changed, and as a result we're having a very difficult funding problem that falls upon the university. I can testify to that because I had to put out $40,000 just for the summer term because there was some uncovering of students even though there are a fair number of students, in fact, who have personal funds and pay their own way.

On page 29 is a breakdown of the science, nonscience configuration. I took two departments who have approximately the same number of graduate students so that there could be some comparison. It's not surprising the differentiation that occurs, but in biochemistry and molecular cell biology 68 percent of the funding comes from the university, 22 and four-tenths of 1 percent comes from grants, Government traineeships and research assistantships. And only 5 percent from private or corporate fellows and I want to talk just briefly about that.

	BMCB (45 students)	English (44 students)
University Fellowship and Scholarship Support	67,372	54,301
TA	63,159	54,073
Government Traineeship	17,479	0
Government Grant RA	25,605	0
U.S. Private or Corporation Fellow	9,987	0
Personal Funds	0	15,392
Other	8,234	20,766
Total Support Including Personal Funds	191,836	144,073

For example, on the traineeships a training grant that was supposed to be increased this year from 7 to 12 there was a shortfall there, which on an annual basis will run to about $80,000 on a quarterly basis. In other words about $20,000 would double the traineeship dollars in other words that currently would have come from Federal sources.

The personal funds, as you can see, are zero, which is common in the sciences and the total support is given as $191,836 in terms of dollars. English, I have selected as a nonscience area and as you can well see the university fellowship and TA's are the large support mechanisms, almost equally divided and are somewhat comparable, therefore, to the science departments. There are no Federal funds in support of that. Personal funds are higher, as one would expect. If you take personal funds and other together, in other words, it almost matches the amount of teaching assistant support for our fall quarter or university scholorships for the fall quarter. And I have also included in the written testimony a breakdown of all these figures by department in the column of arts and sciences so that other comparable situations can be discussed.

As far as the overall trend in the college of arts and sciences, if—that's on page 28 of the written testimony, there, as one would expect, the amount of university funding in again the fall quarter, the amount of university funding is greater than in the sciences, 58.6 percent versus 41.4 percent. If one takes away the percentage of support from personal funds and loans you've come down with nonuniversity funds of 29.7 percent. Now, as far as the Federal support was concerned it was 51 percent of all nonuniversity support, 21.4 percent of all support. And this too must be extrapolated in terms of the larger picture.

On page 38 of the written testimony I have provided a breakdown of the support for international students. In the experience at Northwestern it is contrary to some of the generalizations often made. For example, it is often generalized that foreign students are, for the most part, supported by their governments and that the support from either the Federal sources or from the university sources are minimal. The—this is a 1981-82 indepth analysis and I have replicated it for 1982-83, 1983-84 and the comparisons are almost precisely the same. But, you'll notice that if you look at that page that the foreign private government fellowships constitute only 14 percent of an international student's support. That Federal support is 19.7 and it is largely, of course, in the research assistant category and that the primary support, 47 and five-tenths of 1 percent is from institution support, meaning from the university.

University Fellowship	$102,501.00
University Scholarship	101,364.00
GRAT/S	74,970.00
Teaching Assistants App Fund	271,928.99
Teaching Assistants Work/Study	000.00
Departmental Funds	43,935.24
Government Fellowships	10,755.00
Government Traineeships	1,833.33
Research Assistant Govt Grant	243,866.14
Research Assistant Private	8,321.66
U.S. Private Corporate Fellowship	20,177.00
Foreign Private Govt Fellowship	184,807.33
Endowed Fellowship	17,080.00
Outside Aid	13,933.00
Continuing Education	6,831.00
Personal Funds	177,132.00
Loan	5,334.00
Other	16,354.50
	1,301,124.19

One quick look at the loans as a means of support, and that is on, page 41 and 42 of the written testimony and I have there the loans as they were in 1982-83. They are always a little behind in the sense of getting any full picture, but what this amounts to is if you look through that list you'll discover very little support from loans for science and engineering areas and if you include communicative disorders as an aspect of science, meaning speech and language pathology, clinical psychology, learning disabilities and audiology then you find a very heavy loan component and the total loans for the institution at any time will run something like $2.5 million a year for these areas.

If, on page 15, which also comes from the highest achievers study you'll see that an increasing number of the highest achievers in fact needed to borrow over the last three decades, with at least a third of them borrowing by 1976. There is not decent data yet from 1981, from the 14 institutions that participated in this, so that is in a sense the best information that we have at the time.

TABLE 3

LOAN STATUS
STUDENTS ENROLLING IN GRADUATE SCHOOL
CLASSES OF 1956, 1966, and 1976

		Borrowed	Did Not Borrow	Total
Highest Achievers				
1956	N	11	99	110
	%	(10.0)	(90.0)	
1966	N	25	122	147
	%	(17.0)	(83.0)	
1976	N	114	235	349
	%	(32.7)	(67.3)	
Control Group				
1956	N	12	38	50
	%	(24.0)	(76.0)	
1966	N	12	43	55
	%	(21.8)	(78.2)	
1976	N	35	42	77
	%	(45.5)	(54.5)	

If I wanted to—if I summarized I would say that among the things that are very important, so it seems to me and I think Northwestern and to a great many other institutions, one, we have to find some incentives to get the highest achievers into the pool of science and technology potentials. Second, this decline in trainee traineeships simply has to be arrested and reversed in terms of its decline. Third, that something a little different, that there must be more favorable policy in some of the Federal agencies with regard to research assistants. It's normally the first item that is struck from a principal investigator's budget and this causes an enormous amount of difficulty and puts a great deal of tension upon the sources and strain on the sources of the university. Fourth, stability. Stability in funding. If there is some at least early warning systems that something is occurring, a university can adjust, but at this moment at least in our structure we have strained ourselves almost to the limit and if a new and unexpected change occurs it is very difficult for the university to adjust rapidly enough. And therefore, I think that the burden on the university has to be eased in some—in fact I think the burden on the university is sorely underestimated and that the graduate students are treated a little bit like stepchildren in this process. We also need thoughtful policies for funding of and increasing the number of minorities and women. And finally, we have not really utilized the Federal programs that are need-based, in particular work/study.

So, those are comments that I would make at this time. Thank you.

[The prepared statement of Dr. Ver Steeg follows:]

TESTIMONY ON FUNDING MECHANISMS FOR SCIENCE AND ENGINEERING EDUCATION

BEFORE

THE TASK FORCE ON SCIENCE POLICY
UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY

BY

CLARENCE L. VER STEEG
DEAN OF THE GRADUATE SCHOOL
NORTHWESTERN UNIVERSITY

JULY 10, 1985

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Appendix A

Breakdown in Graduate School Sources in Types of Financial Support

Appendix B

Summary: Sources of Funding by School

Mr. Chairman and Members of the Committee:

I appreciate this opportunity to appear before the Task Force on Science Policy of the Committee on Science and Technology of the House of Representatives as it deliberates upon the development of future federal policy which will best serve the national interest. I found the booklet prepared for this series of hearings, An Agenda For A Study of Government Science Policy, a model of its kind--comprehensive, lucid, and packed with penetrating questions.

My principal contribution to this special panel on the funding mechanisms for science and engineering education will be to display how these mechanisms operate at Northwestern University. On the basis of this data, as well as my experience with graduate study and research over the past decade, I shall offer recommendations regarding the optimum mechanisms for future funding. In this process I shall compare science and non-science funding--as the letter of Congressman Don Fuqua addressed to me, dated 24 June 1985, requested.

This presentation is organized in seven sections:

1) Postgraduate Choices of Undergraduate Highest Achievers;

2) Overall Graduate Student Funding by Source: Northwestern University;
3) Funding Mechanisms For Technology: Northwestern University;
4) Funding Mechanisms For Science and Non-Science: Northwestern University;
5) Funding Mechanisms for International Students: Northwestern University;
6) Loans as a Funding Mechanism: Northwestern University;
7) Summary and Recommendations.

My profound advocacy for a strong and stable federal policy in support of science and technology is rooted in a comprehensive study made more than two decades ago. As the chairman of a committee at Northwestern University to plan and project the future of the University, it became obvious to me, even though my background is in the humanities, that the development of science and technology was not only vital to institutional intellectual growth but also a prime national concern. My position is based in large part on the needs of the twenty-first century. During the late Middle Ages, scholars focused on the accuracy of texts and theological disquisitions as a way of seeking knowledge and truth. In the eighteenth century, the focus of this search broadened to include philosophy and rhetoric, as well as the beginnings of modern science. For the twenty-first century, science and engineering are obviously keystones--not exclusively so to be sure--in the search for knowledge and truth. Without the strictest attention to the promotion and nourishment of science and technology, the society will more than suffer; it will fail. In this context, the importance of the study in which the Committee on Science and Technology is engaged, in my judgment, cannot be overstated.

POSTGRADUATE CHOICES OF UNDERGRADUATE HIGHEST ACHIEVERS

To determine whether the proportion of undergraduates with outstanding academic records enrolling in graduate school in the 1980s is as large as it was in the 1950s, 1960s, and 1970s, The Graduate School at Northwestern University undertook a commission from the Graduate Research Project of the Consortium on Financing Higher Education (COFHE) to conduct a study of undergraduate "highest achievers" over a period of three decades. Fourteen major research universities participated, using a generally uniform definition of highest achievers. A control group was developed, made up of a random selection from the same graduating classes. The years selected were 1956, 1966, 1976, and 1981.

The major findings were as follows:

1) Highest achievers in the four classes surveyed between 1956 and 1981 consistently enrolled in graduate school in greater proportion than members of the control group.

2) The proportion of highest achievers enrolling in graduate school reached a peak in 1966 and subsequently declined dramatically.

3) The proportion of highest achievers enrolling in professional school increased after 1956; by 1976 it exceeded the proportion of highest achievers enrolling in graduate school.

4) Between 1976 and 1981 the proportion of highest achievers enrolling in professional school declined, while the proportion of highest achievers enrolling in graduate school stabilized.

5) The generalizations stated in 1), 2), 3), and 4) apply to females and males, although the decline in the proportion of highest achievers enrolling in professional school between 1976 and 1981 was a result of a decrease in the proportion of male enrollment accompanied by stability in female enrollment.

6) The increase in the proportion of highest achievers and the control group enrolling in graduate school between 1956 and 1966 was a result of increased enrollment by social science majors.

7) The decline in the proportion of highest achievers and the control group enrolling in graduate school between 1966 and 1976, as well as the subsequent stability between 1976 and 1981, was consistent across the principal fields of undergraduate study.

8) Over the period from 1956 to 1981 the proportion of highest achievers receiving fellowships exceeded the proportion of the control group receiving fellowships.

9) Although the loan data is incomplete, the dependency of highest achievers on loan programs to finance post-baccalaureate education increased steadily between 1956 and 1976.

10) Although the proportion of highest achievers choosing graduate study was sharply reduced between 1956 and 1981, the quality of those who make this choice has not diminished.

The graphs (Figures 1-7) and tables (Tables 1-3) which follow vividly portray these findings.

FIGURE 1

Post-Baccalaureate Enrollment
Classes of 1956, 1966, and 1976

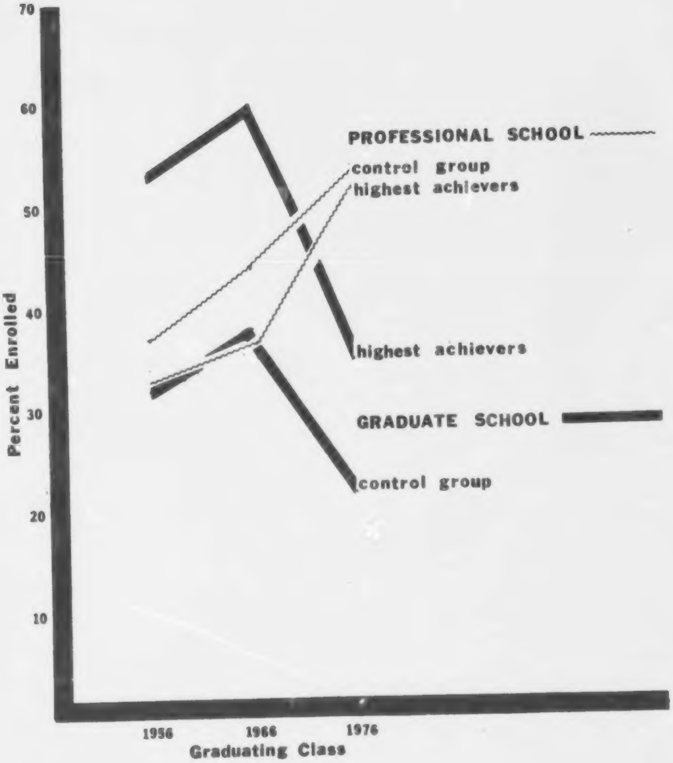

FIGURE 2

GRADUATE SCHOOL ENROLLMENT
Classes of 1956, 1966, and 1976

By Undergraduate Major

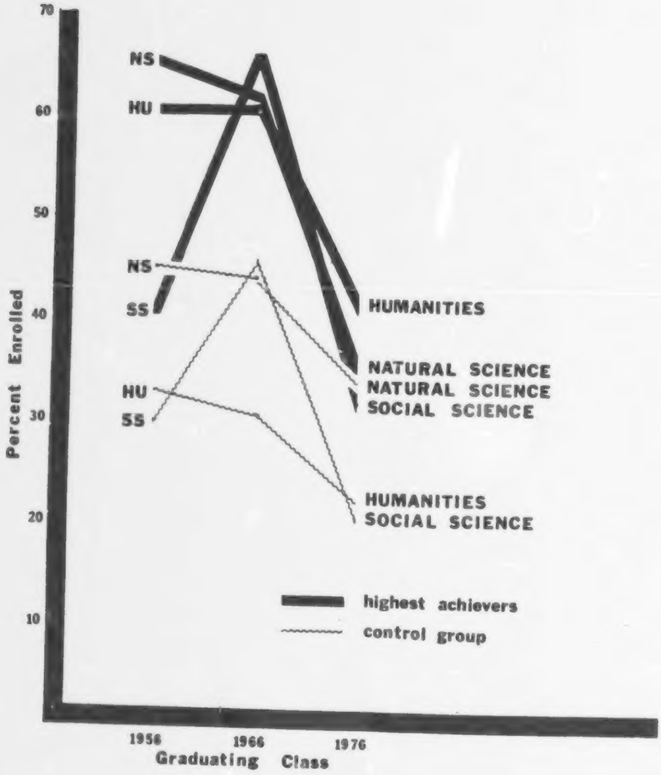

FIGURE 3

Post-Baccalaureate Enrollment
Classes of 1956, 1966, and 1976

Highest Achievers by Gender

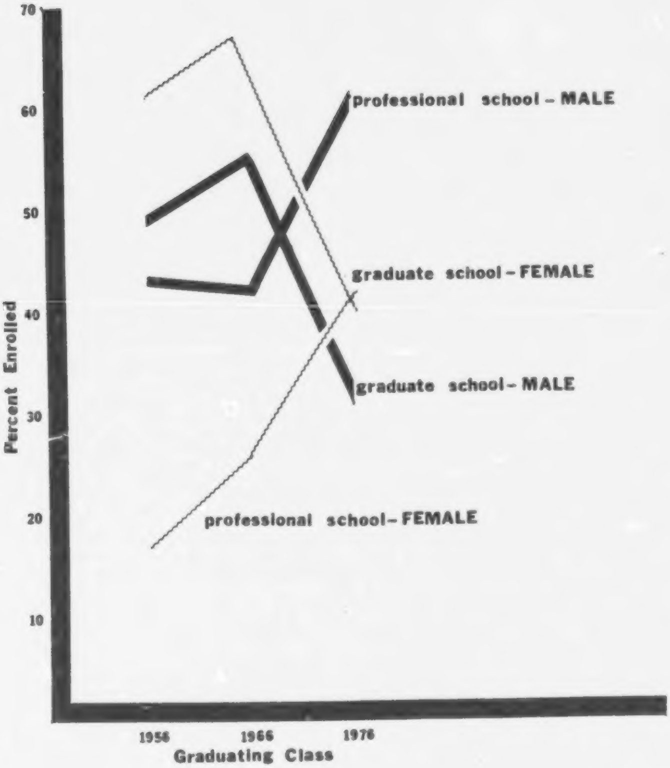

FIGURE 4

Post-Baccalaureate Enrollment
Classes of 1956, 1966, and 1976

Control Group by Gender

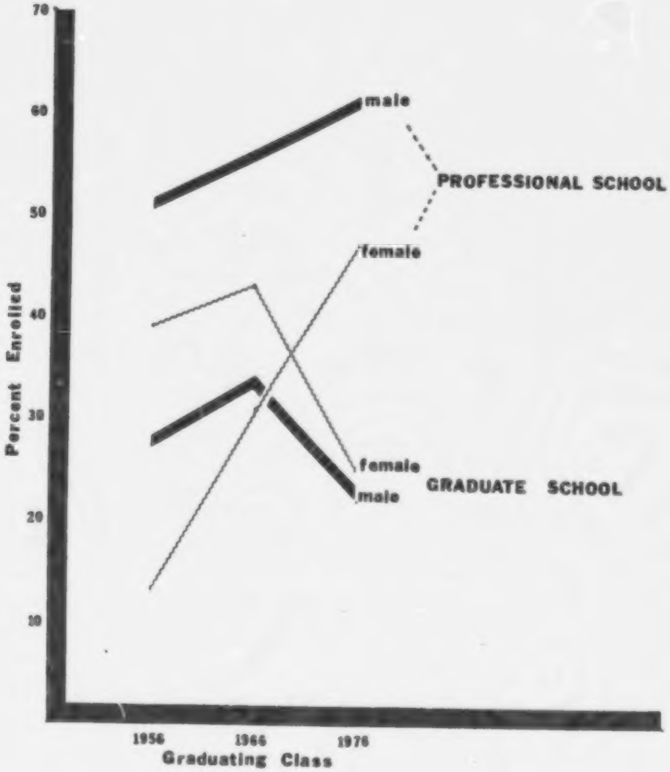

FIGURE 5

Post-Baccalaureate Enrollment
Within Two Years of Graduation
Classes of 1976 and 1981

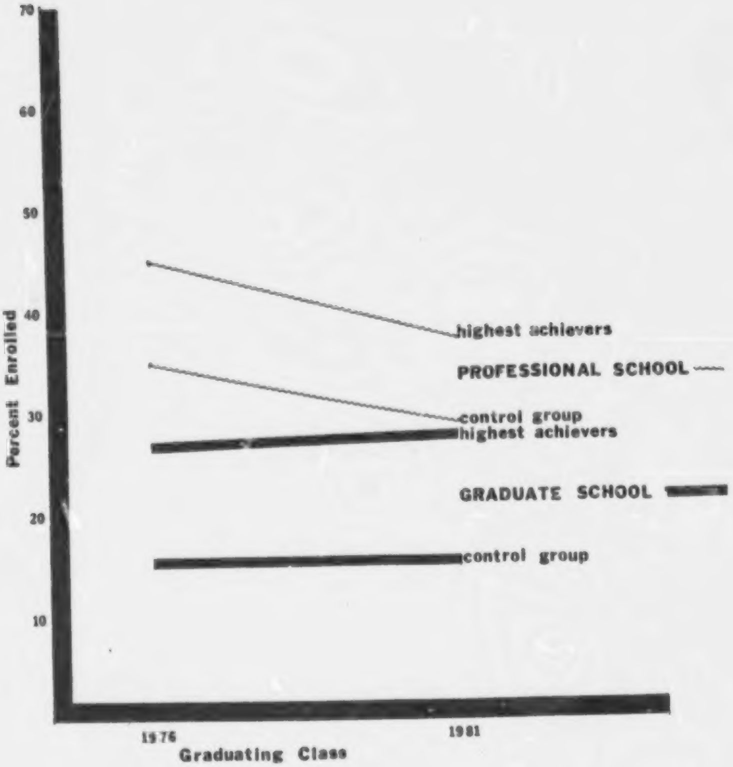

FIGURE 6

GRADUATE SCHOOL ENROLLMENT
Within Two Years of Graduation
Classes of 1976 and 1981

By Undergraduate Major

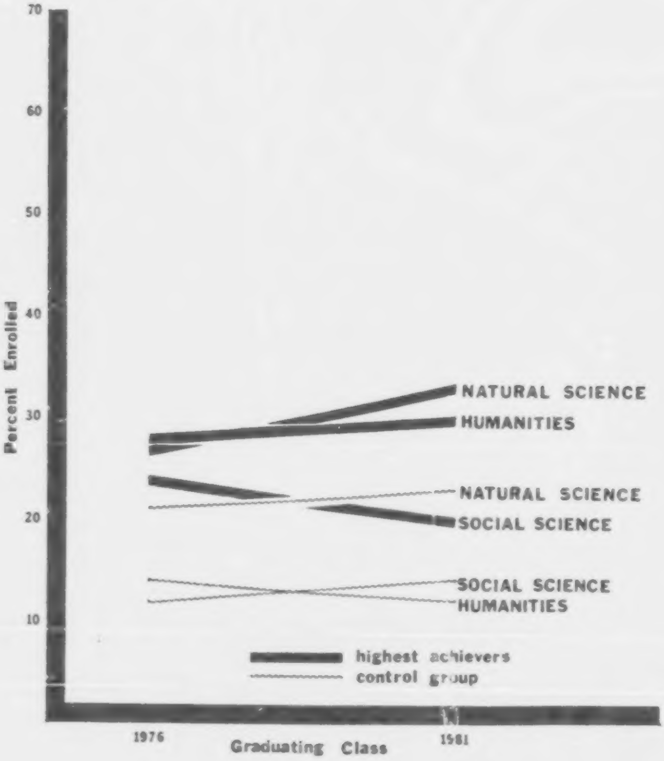

FIGURE 7

Post-Baccalaureate Enrollment
Within Two Years of Graduation
Classes of 1976 and 1981

Highest Achievers by Gender

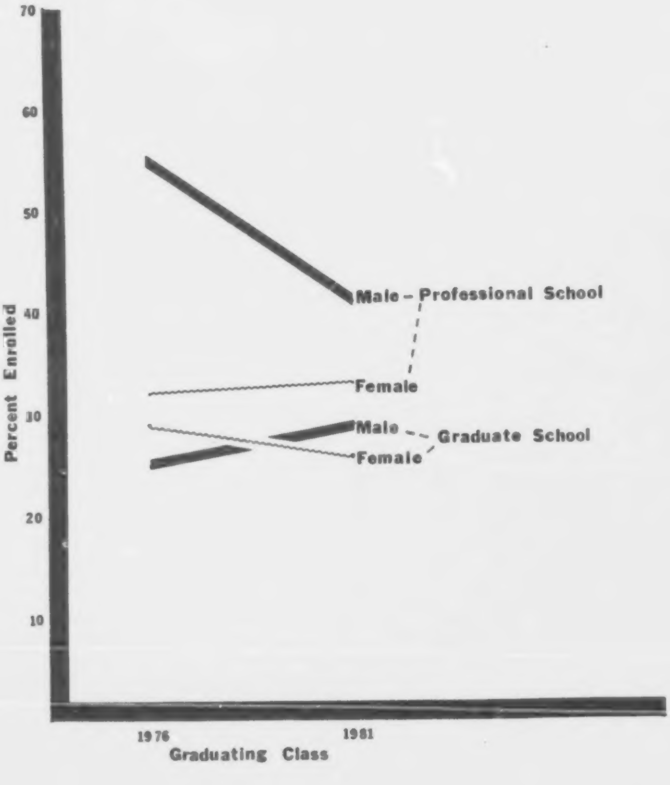

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TABLE 1

FELLOWSHIP SUPPORT
STUDENTS ENROLLING IN GRADUATE SCHOOL
CLASSES OF 1956 AND 1966

		No Fellowship	Fellowship	Total
Highest Achievers				
1956	N	58	52	110
	%	(52.7)	(47.3)	
1966	N	30	117	147
	%	(20.4)	(79.6)	
Control Group				
1956	N	38	12	50
	%	(76.0)	(24.0)	
1966	N	36	19	55
	%	(65.5)	(34.5)	

TABLE 2

FELLOWSHIP SUPPORT
FIRST YEAR OF GRADUATE STUDY
STUDENTS ENROLLING IN GRADUATE SCHOOL
CLASSES OF 1976 AND 1981

		No Fellowship	Fellowship	Total
Highest Achievers				
1976	N	111	159	270
	%	(41.1)	(58.9)	
1981	N	102	164	266
	%	(38.3)	(61.7)	
Control Group				
1976	N	32	19	51
	%	(62.7)	(37.3)	
1981	N	26	23	49
	%	(53.1)	(46.9)	

TABLE 3

LOAN STATUS
STUDENTS ENROLLING IN GRADUATE SCHOOL
CLASSES OF 1956, 1966, and 1976

		Borrowed	Did Not Borrow	Total
Highest Achievers				
1956	N	11	99	110
	%	(10.0)	(90.0)	
1966	N	25	122	147
	%	(17.0)	(83.0)	
1976	N	114	235	349
	%	(32.7)	(67.3)	
Control Group				
1956	N	12	38	50
	%	(24.0)	(76.0)	
1966	N	12	43	55
	%	(21.8)	(78.2)	
1976	N	35	42	77
	%	(45.5)	(54.5)	

OVERALL GRADUATE STUDENT FUNDING BY SOURCE: NORTHWESTERN UNIVERSITY

In discussing support of graduate students, as distinguished from professional students and undergraduates, it is essential to remember that such support is given on the basis of merit rather than need. However, these students, when they demonstrate need, can also qualify for need-based support.

For example, an applicant of superior talent is admitted to graduate school. Once admitted, that student may receive some support such as a partial tuition scholarship or a stipend. The scholarship will, more likely than not, be awarded by the university, that is from institutional funds. The stipend could come from a variety of sources, of which the university is one. If that superior student demonstrates need, the student may qualify for a National Direct Student Loan (NDSL) or, in the case of work/study, payment in exchange for the performance of service associated with his or her educational program, more often than not by teaching undergraduates or serving as a research assistant in a laboratory. As a brief aside, it should be noted that demonstrated need by superior graduate students greatly exceeds the NDSL or work/study dollars available, because this funding has been largely absorbed by need-based, campus-based undergraduate student aid.

The data which follows on support mechanisms for graduate students at Northwestern University may not necessarily be representative of all research universities. Northwestern is a private rather than a public institution. Public institutions generally tend to have more graduate student teaching assistants--at least in numbers--than private institutions. Northwestern is a comprehensive university, that is it includes a large number of professional schools--as opposed, for example, to the California Institute of Technology or Princeton. In many respects, Northwestern University's development as a research university is relatively recent compared with private institutions such as Columbia, the University of Chicago, or Stanford. Therefore, those institutions tend to have a substantially larger proportion of graduate research assistants. In short, each university has a special personality based on its history, its mission, whether private or public, and similar considerations.

However, to examine the specific support mechanisms of a single institution is useful for developing pertinent questions and sharpening issues. Obviously, such an examination will not answer all the questions raised.

The chart which follows provides a breakdown of the various mechanisms of support at Northwestern University in terms of percentages for all graduate students. The chart has three main headings: GRANT SUPPORT (requiring full-time study but no service); SERVICE REQUIRED SUPPORT (self explanatory but it could be classified as self support); and SELF SUPPORT (personal funds plus loans). Each of the first two mainheads is broken down into University and non-University support. The years sampled include 1976/1977, 1980/1981, and 1984/1985.

The "University Appropriated" GRANT SUPPORT has remained relatively constant between 14 and 15 percent, but the "Non-University" GRANT SUPPORT has declined precipitously. Between 1976/1977 and 1980/1981 it was reduced by 50 percent, from 11.9 percent to 6.5 percent. It continues to be more than 28.5 percent below the 1976/1977 level.

This sharp decline in Non-University GRANT SUPPORT is the result almost exclusively of a decline in government traineeships--more than 77 percent--plus a 50 percent decline from 1976/1977 to 1980/1981 in fellowships provided by United States corporations. Government fellowship support declined 50 percent between 1976/1977 and 1980/1981; but it has almost regained its 1976/1977 level. However, the percentage of support from government fellowships in relation to the percentage provided by all funding mechanisms is relatively small--1.5 percent.

Under SERVICE REQUIRED SUPPORT, funding by Northwestern University between 1976/1977 and 1984/1985 increased 11 percent. This increase resulted from a decision by Northwestern to provide those students who serve as research assistants on federal grants of principal investigators with tuition scholarships. Principal investigators at Northwestern, in seeking funding for their research, found themselves at a disadvantage in competing with their peers, because federal agencies were, and are, reluctant to include the cost of tuition as part of the cost of using graduate students as research assistants in the laboratories of principal investigators.

In the category of "Non-University Funds" under SERVICE REQUIRED SUPPORT, funding of research assistants from federal sources has declined by about 17 percent from 1976/1977 to 1984/1985. For a brief period, work/study became an important source of funding for graduate students engaged as teaching assistants; but as need-based aid for undergraduates became increasingly acute, the number of graduate students that could be supported from work/study as a level-funding source declined. In fact, work/study as a potential source to support graduate students, either as research assistants or as teaching assistants, has never been fully utilized.

Overall SELF SUPPORT has ranged between 40 and 45 percent. Loans as percentage of self support has declined, in part because of federal restrictions and in part because loan limits do not cover tuition costs. Section Six in this presentation will discuss loans separately.

NORTHWESTERN UNIVERSITY
The Graduate School

GRADUATE STUDENT FUNDING BY SOURCE
Comparison among Fall Quarters 1976/77, 1980/1981 and 1984/85

	Percent of Total Support*		
	1976/77	1980/81	1984/85
GRANT SUPPORT			
University Appropriated Funds	15.3	13.9	14.2
Fellowships	10.3	10.8	10.5
Scholarships	5.0	3.1	3.7
Non-University Appropriated Funds	11.9	6.5	8.5
Endowed Fellowships	**	.9	.9
Government Fellowships	1.6	.8	1.5
Government Traineeships	5.3	2.1	1.2
U.S. Private/Corporate Fellowships	4.6	.5	2.2
Foreign Private/Government Fellowships	**	1.1	2.2
Outside Graduate Fellowships	.4	1.1	.5
SERVICE REQUIRED SUPPORT			
University Funds for Service	19.7	17.8	21.9
GRAT/S ***	-0-	3.5	4.4
TA: Appropriated Funds	19.7	13.3	16.7
TA: Work/Study Matching Funds	-0-	1.0	.8
Non-University Appropriated Funds for Service	11.0	17.1	15.2
Departmental Sources	**	3.2	2.8
TA: Work/Study Federal Portion	-0-	4.1	1.8
RA: Government	10.6	8.4	8.8
RA: Private	.4	.9	.8
Continuing Education	**	.5	1.0
SELF SUPPORT			
Loans	7.4	8.1	5.7
Personal Funds - tuition & non-tuition	34.7	36.1	34.3
Other	-0-	.5	.2
TOTAL	100.0	100.0	100.0

*These columns show the percent of total support of all full-time students from a particular source. The total support amount is derived by multiplying the student budget for maintenance and tuition by the full-time enrollment. The tuition figure is prorated to reflect the reduced tuition rates when appropriate.

** The 1976/77 Financial Aid Survey did not account for these data.

*** GRAT/S stands for Graduate Research Assistant Tuition Scholarship

FUNDING MECHANISMS FOR TECHNOLOGY: NORTHWESTERN UNIVERSITY

This section supplies data on support mechanisms for graduate students in the Technological Institute at Northwestern University in general, and then broken down by departments. Noting always that the dollars represent only the Fall Quarter of 1984/1985 and, therefore, must, in this case, be multiplied by four quarters to include the entire year, Northwestern University provided $1,103,345 (49 percent) of the graduate student support, and non-University sources provided $1,152,518 (51 percent). If the $413,094 of personal funds and loans are subtracted from the non-University support, the true figure is $739,442 or not quite 33 percent. The federal dollars of student support was $447,250 (20 percent). Of this number, only $36,979 (1.5 percent) did not require the performance of service. In most cases students served as research assistants in the laboratories of principal investigators. A surprising figure is that of student support from personal funds and loans which amount to $413,194 (18 percent), almost the equivalent of federal support. Compared with the 40-45 percent of personal funds and loans as a funding mechanism for graduate students overall, however, the figure for the Technological Institute is on the lower end of the spectrum.

Teaching assistantships do not represent as large a funding mechanism in the Technological Institute as they do in the College of Arts and Sciences. Courses in the Technological Institute are deliberately kept smaller and are taught by full-time professors. Therefore, there are fewer discussion or laboratory sections such as one finds in the College of Arts and Sciences. On the other hand, postdoctoral assistants are not as readily available in engineering as in other sciences, so that the demand for graduate students as research assistants in laboratories of principal investigators is acute. Principal investigators often have a difficult time obtaining sufficient funding to support the research assistants needed to complete their researches. This lack constitutes an extremely serious problem. It should also be noted that traineeships do not exist in the Technological Institute; traineeships, on the whole, are a neglected support mechanism.

The breakdown of support mechanisms by department in the Technological Institute suggests a number of generalizations:

1) In terms of percentage, more students in Biomedical Engineering and Electrical Engineering/Computer Science are supported on personal funds than in other departments in the Technological Institute.

2) Federal grants in Chemical Engineering, Civil Engineering, and Materials Science are critical to ongoing graduate student support and research. Yet funding, especially in Chemical Engineering as it affects research assistants, is difficult to obtain because of swiftly changing federal priorities.

3) In almost every department in the Technological Institute, except for Materials Science, the greatest percentage of student support comes from the University.

4) Except for Chemical Engineering, corporate support for graduate students is surprisingly limited.

1984/85

BREAKDOWN IN GRADUATE SCHOOL SOURCES AND TYPES OF FINANCIAL SUPPORT

Technological Institute

	University Funds	Non-University Funds
University Fellowship	412123 98	
University Scholarship	28[illegible]8 -	
GRAT/S	256513 -	
T.A. - allocated funds	112408 -	
T.A. - work-study	15507 0	36112 20
Departmental funds	38235 13	
Government Fellowship		369779 98
Government Traineeship		
Research Asst - govt grant		406650 17
Research Asst - private		96007 10
US private or corp. fellow		116399 99
Foreign private or govt fellow		111981 87
Endowed fellowship	33522 -	
Grant or scholar not thru NU		8982 -
Continuing Education		
Personal funds		339936 -
Loans		78603 -
Other		8982 -
TOTALS	1109345 81	1152618 42

SOURCES OF FINANCIAL SUPPORT FOR GRADUATE STUDENTS
FALL QUARTER, 1984/1985

	1 Biomedical Engineering	2 Chemical Engineering	3 Civil Engineering	4 EE/CS	5 Industrial Engineering	6 Applied Mathematics
University Fellowship	21359 –	29568 98	70595 –	69697 –	55190 –	46600 –
University Scholarship	5988 –		6263 –	998 –		2994 –
GRAT/S	2719 –	32459 –	61091 –	20979 –	8157 –	8880 –
T.A. - allocated funds	15907 –	23849 –	35368 –	184356 –	33368 –	18839 –
T.A. - work-study		5169 –				
Departmental funds		10067 –	2250 –	8342 –	4900 –	
Government Fellowship		8042 –	9764 –			5019 –
Government Traineeship						
Research Asst. - govt grant	23156 –	55961 –	89266 30	27796 –	10110 –	15879 98
Research Asst - private			11499 –		4560 –	
US private or corp. fellow	5966 –	65829 66	10717 –	9259 –		998 –
Foreign private or govt fellow	5988 –	10255 –	13748 –	20972 87	24950 –	
Endowed Fellowship	4800 –		2400 –	8978 –		2400 –
Grant or scholar not thru		2994 –		2994 –		2994 –
Continuing Education						
Personal funds	23887 –	22254 –	54387 –	168879 –	24735 –	10055 –
Loans	19085 –	11884 –	10942 –	20730 –	6727 –	
Other			2994 –		5988 –	
TOTALS	126954 –	327921 64	381280 80	541475 87	176685 –	114653 98

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SOURCES OF FINANCIAL SUPPORT
FALL QUARTER, 1984/1985

	Materials Science	Mechanical Engineering	Nuclear Engineering	Theo + Appl'd Mechanics	Urban Systems		Total TECH
University Fellowship	27965 -	30443 -	5319 -	8388 -	5019 -		412123 98
University Scholarship	4267 -	7485 -		998 -			28993 -
GRAT/S	98984 -	17587 -		4161 -			256513 -
T.A. - allocated funds	3173 -	10338 -		7619 -	5169 -		332408 -
T.A. - work-study							5169 -
Departmental funds	2860 84	9815 29					38235 13
Government Fellowship	12487 98	1667 -					36479 98
Government Traineeship							
Research Asst - govt grant	140770 34	35123 56		8990 -			406653 18
Research Asst - private	14173 -	10662 10		5113 -			46007 10
US private or corp. fellow	21182 33	2948 -					116349 99
Foreign private or govt fellow	1935 -	30511 -		3992 -	2994 -		111851 87
Endowed Fellowship	2400 -	8244 -		4800 -			33522 -
Grant or scholar not thru MU							8982 -
Continuing Education							
Personal funds	6736 -	20564 -		2994 -			334486 -
Loans	9764 -	476 -					78608 -
Other							8982 -
TOTALS	346648 49	185863 95	5319 -	49055 -	13182 -		2255864 23

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FUNDING MECHANISMS FOR SCIENCE AND NON-SCIENCE: NORTHWESTERN UNIVERSITY

As might be expected, the overall support of graduate students in the College of Arts and Sciences at Northwestern University depends upon University resources even more than does the Technological Institute. Noting once again that the dollar figures represent only the Fall Quarter and thus must be multiplied to obtain an annual dollar figure, University support for the graduate students in the College of Arts and Sciences in 1984/1985 amounted to $1,777,359 (58.6 percent) and non-University support amounted to $1,251,499 (41.4 percent). Deducting the self support of $351,737, the non-University sources of support, in effect, totaled $899,761 (29.7 percent). Federal support amounted to $649,145 or 51.8 percent of the non-University support and 21.4 percent of all support.

To illustrate the operation of the different support mechanisms as they affect science and non-science departments, a comparison between the Department of Biochemistry, Molecular Biology and Cell Biology (BMCB) and the Department of English for the Fall Quarter 1984/1985 is illuminating:

	BMCB (45 students)	English (44 students)
University Fellowship and Scholarship Support	67,372	54,301
TA	63,159	54,073
Government Traineeship	17,479	0
Government Grant RA	25,605	0
U.S. Private or Corporation Fellow	9,987	0
Personal Funds	0	15,392
Other	8,234	20,766
Total Support Including Personal Funds	191,836	144,073

Science departments such as Biochemistry, Molecular Biology and Cell Biology tend to support all their students with tuition and stipend from a variety of funding sources for twelve months of the year. In doing so they try to maximize their sources. Attempting to accomplish this objective often raises serious problems, in part because of unstable funding and in part because of the mismatch that occurs between the research focus of the principal investigator who has funding and the graduate student whose research interests do not match that of the principal investigators within a sponsored program that has been reviewed by scholarly peers as to its quality.

In the Department of English, about 25 percent of the students are not supported, a lower percentage than the overall average of 40-45 percent. Those departments in the College of Arts and Sciences which approximate the average of 40-45 percent in terms of support from personal funds, each for a different reason, are Anthropology, Art History, Classics, Economics (which seems surprising but is explicable), German, History and Literature of Religions, Political Science, and Sociology. In the School of Education, the percentage of students using personal funds for support is 54 percent; in the School of Music, 49 percent, and in the School of Speech, 38 percent.

This forthright display of institutional data can be seriously misinterpreted to suggest that Biochemistry, Molecular Biology and Cell Biology is well supported. Appropriately understood, the data reveals a contrary story. University sources provide $130,531 (68 percent). In contrast, federal sources provide only $43,084 (22.4 percent). Corporations provide a modest $9,987 (5 percent). Such data paint a bleak picture; and the future outlook is no brighter. The training grant of Biochemistry, Molecular Biology and Cell Biology, for example, was scheduled to support an additional five students in 1985/1986, but the agency officer reported that this commitment could not be met. This burden of support, once again, falls unexpectedly on the University at a cost in excess of $80,000. Moreover, the chairman of the department and I, together with University development officers, have presented an attractive package for graduate student support to corporations which depend upon a supply of quality life scientists--but without success.

Fall Quarter - 1984/85

BREAKDOWN IN GRADUATE SCHOOL SOURCES
AND TYPES OF FINANCIAL SUPPORT
College of Arts and Sciences

Wilson Jones
Form 30-8

	University Funds	Non-University Funds
University Fellowship	441309 97	
University Scholarship	71663 50	
GRAT/S	127635 90	
T.A. - allocated funds	990961 05	
T.A. - work-study	59921 21	139816 15
Departmental funds	34043 –	
Government Fellowship		79813 65
Government Traineeship		32115 –
Research Asst - govt grant		398331 09
Research Asst - private		29373 60
US private or corp. fellow		60633 –
Foreign private or govt fellow		69060 01
Endowed fellowship	51426 01	
Grant or scholar not thru NU		24525 90
Continuing Education		66494 66
Personal funds		199944 50
Loans		151793 –
Other		5729 –
TOTALS	1777359 74	1251499 16

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Wilson Jones

SOURCES OF FINANCIAL SUPPORT FOR GRADUATE SCHOOL STUDENTS
FALL QUARTER, 1984/1985

	Anthropology	Art History	Art Theory	BMBCB	Biological Sciences	Ecology + Evol Biol	Chemistry
University Fellowship	2668035	9138 –	2100 –	4584602		5099 –	26095 –
University Scholarship	4491 –	2994 –		7100 –			2994 –
GRAT/S	285650			11426 –			743 0 –
T.A. - allocated funds	4573650	15282 –	15282 –	58065 –		12563 –	144327 –
T.A. - work-study	10188 –	8192 –		5094 –			
Departmental funds	4200 –			5660 –			14138 –
Government Fellowship	4660 –						10038 –
Government Traineeship	10973 –			17979 –			
Research Asst - govt grant	443750			25608 –			201300 –
Research Asst - private				942 –			1750 –
US private or corp. fellow	5499 –			9987 –			7875 –
Foreign private or govt fellow							7144 –
Endowed Fellowship				200001			2075 –
Grant or scholar not thru N							
Continuing Education		1408 –					
Personal funds	10978 –	5200 –	5676 –		275 –	275 –	550 –
Loans	14619 –	5409 –	3334 –	2629 –		1000 –	1917 –
Other	2994 –						
TOTALS	14830785	47623 –	26392 –	19183603	275 –	18932 –	500543 –

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SOURCES OF FINANCIAL SUPPORT FOR GRADUATE SCHOOL STUDENTS
FALL QUARTER, 1984/1985

	Neurobiology & Physiology	Classics	Economics	English	Geography	Geological Sciences	German
University Fellowship	20376 –	2100 –	62814 –	39160 –		15432 –	
University Scholarship			11789 –	15141 –			
GRAT/S			5438 –			13310 –	
T.A. - allocated funds	28541 –	8192 –	16865 91	33617 –	998 –	25470 –	30220 –
T.A. - work-study			5094 –	20376 –			8192 –
Departmental funds	1140 –		2375 –				
Government Fellowship	8023 –					10038 –	
Government Traineeship							
Research Asst - govt grant	8315 –		77049 89			26416 –	
Research Asst - private						7698 –	
US private or corp. fellow			17620 –	600 –		9944 –	
Foreign private or govt fellow			25612 33	5988 –			
Endowed Fellowship		2944 –	10168 –	4320 –			
Grant or scholar not thru [illegible]			8863 50				
Continuing Education		1975 –	12371 –	5652 –		2098 –	
Personal funds	6203 –	2334 –	45182 –	15392 –		6263 –	5265 –
Loans	1765 –	600 –	12839 –	3767 –		1188 –	
Other							
TOTALS	69450 –	18195 –	314236 63	144073 –	998 –	117807 –	43677 –

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SOURCES OF FINANCIAL SUPPORT FOR GRADUATE SCHOOL STUDENTS
FALL QUARTER, 1984/1985

		1 History	2 History + Liter Religions	3 Linguistics	4 Mathematics	5 Philosophy	6 Physics	7 Political Science
1	University Fellowship	15038 70	10188 –	29884 70	29820 –	17382 –	25912 –	12853 70
2	University Scholarship	3269 –	1997 –	6986 –				
3	GRAT/S						10326 –	
4	T.A. - allocated funds	41595 –	13286 –	29692 66	72074 –	30576 98	102540 –	38927 –
5	T.A. - work-study	16384 –	8192 –	5169 –	31666 –	30042 36		18380 –
6	Departmental funds	2100 –						2330 –
7	Government Fellowship	9320 65		9320 –			5104 –	7324 –
8	Government Traineeship							
9	Research Asst - govt grant				9062 50		71351 –	
10	Research Asst - private						3131 –	2898 –
11	US private or corp. fellow	8619 –						5494 –
12	Foreign private or govt fellow	4144 –					4666 68	11757 –
13	Endowed Fellowship	14342 –			5988 –	2994 –		4059 –
14	Grant or scholar not thru N			4944 –				
15	Continuing Education			1325 –	13056 66	6804 –		4141 –
16	Personal funds	10517 –	6491 –	13659 50	6263 –	10978 –	275 –	28513 –
17	Loans	11851 –	4167 –	7040 –	400 –	6901 –	4057 –	24837 –
18	Other							1333 –
19	TOTALS	141874 35	41821 –	95726 86	168330 16	105678 34	226642 68	162832 70

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SOURCES OF FINANCIAL SUPPORT FOR GRADUATE STUDENTS
FALL QUARTER, 1984/1985

Wilson Jones

	Psychology	French Italian	Spanish Portuguese	Slavic	Sociology		Total CAS
University Fellowship	15932 -				31183 -		441809 47
University Scholarship	10861 50				5041 -		71663 50
GRAT/S	3442 -				1497 -		127635 50
T.A. - allocated funds	39637 -	47946 -	30564 -	5094 -	33662 -		990861 05
T.A. - work-study	19482 -	5094 -			8192 -		199737 36
Departmental funds		2100 -					34043 -
Government Fellowship	5019 -				15037 -		78883 65
Government Traineeship	3663 -						32115 -
Research Asst.- govt grant	16183 20				25953 -		398331 09
Research Asst - private	12454 60						29373 60
US private or corp. fellow							60633 -
Foreign private or govt fellow					4698 -		64060 01
Endowed Fellowship	2500 -						51426 01
Grant or scholar not thru NU					5874 -		24325 50
Continuing Education	10406	1408 -			5920 -		66494 66
Personal funds	13025 -	4990 -	998 -	1273 -	13603 -		199944 50
Loans	17946 -	725 -	192 -		18610 -		151793 -
Other					1402 -		5729 -
TOTALS	172551 30	62263 -	31754 -	6367 -	170672 -		3028858 90

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FUNDING MECHANISMS FOR INTERNATIONAL STUDENTS: NORTHWESTERN UNIVERSITY

When discussing funding mechanisms for support of graduate students, international students engaged in graduate study become an important and separate subject for review. So far as the experience of Northwestern University is concerned, three misconceptions need to be addressed:

> First, contrary to general belief, tuition and living costs for the majority of international students are generally not paid by the student's own government or by some source outside the University.
>
> Second, again contrary to general assumption, those international students who provide their own funds during the first year seldom have money for subsequent years of graduate study.
>
> Third, that minority of international students who have funds for living expenses usually find themselves facing such severe hardship because of miscalculated living costs that either the students or faculty sponsors request additional financial support from the University.

In the Fall Quarter of 1981/1982, an in-depth study was made by The Graduate School of the funding mechanisms for international students. Studies in subsequent years confirm the reliability of the initial effort, although the dollar figure of support has increased.

The various sources of support for international students for the Fall Quarter 1981/1982--not the entire year--amounted to $1,301,124.19. This total is broken down by funding category as follows:

University Fellowship	$102,501.00
University Scholarship	101,364.00
GRAT/S	74,970.00
Teaching Assistants Apr Fund	271,928.99
Teaching Assistants Work/Study	000.00
Departmental Funds	43,935.24
Government Fellowships	10,755.00
Government Traineeships	1,833.33
Research Assistant Govt Grant	243,866.14
Research Assistant Private	8,321.66
U.S. Private Corporate Fellowship	20,177.00
Foreign Private Govt Fellowship	184,807.33
Endowed Fellowship	17,080.00
Outside Aid	13,933.00
Continuing Education	6,831.00
Personal Funds	177,132.00
Loan	5,334.00
Other	16,354.50
	1,301,124.19

The sources of funding for international students at Northwestern are similar to those for domestic students. Of the $1,301,124, only $184,807 (14 percent) was derived from support of students by their home governments. This sum combined with personal funds amounts to $361,939 (27.8 percent) of the support, less than that of graduate students overall. Support from federal funding, almost exclusively by service as research assistants, amounted to $256,454 or 19.7 percent. The remaining support, about $682,741, or 52.4 percent, comes from institutional funding. Of this sum about one-half can be accounted for by service as teaching assistants. International students, of course, are not eligible for loans, work/study, or other federally administered need-based support mechanisms.

Although the postdoctoral study is a separate subject, it should be noted that the great majority of postdoctoral students in technology at Northwestern University consists of international students. This generalization is less applicable to the sciences, although the number of international postdoctoral appointees is increasing.

LOANS AS A FUNDING MECHANISM: NORTHWESTERN UNIVERSITY

Loans continue to be a key overall source of support for graduate students. But, as the table which follows indicates, loans are not a critical mechanism for support in science and engineering, except for speech and language pathology, clinical psychology, learning disabilities, and audiology. Engineering students borrow more often than science students, but the numbers are modest. Forgivable loans serve a useful purpose.

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RANKING OF DEPARTMENTS BY TYPE OF LOAN DISBURSEMENT
FOR ACADEMIC YEAR 1982/1983

FISL		NDSL		Other		Total	
1. Clinical Psychology	113688	Speech & Lang Path	122598	Speech & Lang Path	163490	Speech & Lang Path	371098
2. Education	109541	Clinical Psychology	81476	Education	139354	Education	299509
3. Speech & Lang Path	85010	Education	50614	Radio, TV, Film	57533	Clinical Psychology	220164
4. Radio, TV, Film	37990	Radio, TV, Film	27336	Audiology	49931	Radio, TV, Film	122859
5. Learning Disabilities	37450	Learning Disabilities	24685	Economics	48271	Learning Disabilities	107135
6. Music	32075	Audiology	20690	Learning Disabilities	45000	Audiology	94659
7. Sociology	29590	Sociology	19667	Theatre	41000	Anthropology	79000
8. Audiology	24038	Psychology	16678	Anthropology	40000	Psychology	72622
9. Anthropology	23000	Anthropology	16000	Psychology	38617	Economics	71515
10. Theatre	20200	Political Science	14214	Chemical Engineering	31030	Sociology	68847
11. Biomedical Engineering	19913	Biomedical Engineering	9975	Political Science	30813	Theatre	65275
12. Economics	17896	Music	9325	Clinical Psychology	25000	Music	56400
13. EE/CS	17500	Communication Studies	8000	Religion	25000	Political Science	55944
14. Psychology	17327	EE/CS	6925	Civil Engineering	23307	EE/CS	46925
15. Civil Engineering	15000	Philosophy	6500	EE/CS	22500	Biomedical Engineering	44888
16. Interpretation	14722	Chemical Engineering	6465	Sociology	19590	Civil Engineering	42967
17. Organization Behavior	13379	Religion	5950	Interpretation	16010	Chemical Engineering	40395
18. Communication Studies	11060	Pharmacology	5800	Linguistics	15850	Religion	39150
19. Political Science	10917	English	5440	English	15330	Interpretation	32899
20. Neuroscience	10800	Art History	5295	Biomedical Engineering	15000	Hist & Lit of Religions	30920
21. Interdepartmental Speech	10000	Linguistics	5070	Music	15000	English	28770
22. Linguistics	10000	Neuroscience	5000	Pharmacology	15000	Pharmacology	25130
23. Philosophy	9600	Physical Therapy	5000	Materials Science	14046	Philosophy	24695
24. History	8911	Physics	5000	Chemistry	12324	Communication Studies	24060
25. Chemistry	8500	Transportation	5000	Hist & Lit of Religions	10785	Materials Science	21796
26. Religion	8200	Tumor Cell Biology	5000	IE/MS	10000	Chemistry	21624
27. English	8000	Organization Behavior	4689	Philosophy	8595	Organization Behavior	20068
28. Mechanical Engineering	7775	Civil Engineering	4660	History	7595	History	18396

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RANKING OF DEPARTMENTS BY TYPE OF LOAN DISBURSEMENT
FOR ACADEMIC YEAR 1982/1983

	FISL		NDSL		Other		Total	
29.	Physics	7500	Theatre	4075	Nursing	7050	Interdepartmental Speech	18750
30.	Physical Therapy	7000	Interdepartmental Speech	3750	Mechanical Engineering	7000	Physics	17500
31.	Materials Science	6250	Economics	3350	Geological Sciences	6850	His & Lit of Religions	17305
32.	Hist & Lit of Religions	5000	History	2890	Art Theory	5000	Mechanical Engineering	15875
33.	Theoretical & App Mech	5000	Theoretical and App Mech	2230	Communication Studies	5000	Neuroscience	15800
34.	Transportation	5000	BMBCB	2200	Interdepartmental Speech	5000	Geological Sciences	13140
35.	Tumor Cell Biology	5000	Interpretation	2167	Marketing	5000	Transportation	12165
36.	Geological Sciences	4600	Geological Sciences	1690	Mol Bio & Biochem	5000	Physical Therapy	12000
37.	Biological Sciences	4560	Hist & Lit of Religions	1600	Physics	5000	Materials Science	10000
38.	Neurobiology	4500	Art Theory	1500	Neurobiology	3959	Tumor Cell Biology	10000
39.	Pharmacology	4330	Materials Science	1500	Physiology	3600	Neurbiology	8459
40.	Comparative Literature	3336	Mechanical Engineering	1100	Microbiology	3500	BMBCB	8030
41.	Chemical Engineering	2900	Chemistry	800	BMBCB	3430	Art History	7995
42.	BMBCB	2400	French & Italian	500	Ecology	2986	Theoretical & App Mechanics	7230
43.	Spanish & Portuguese	2000			Art History	2700	Nursing	7050
44.	Microbiology	1667			Transportation	2165	Art Theory	6500
45.	Mathematics	1640			Organization Behavior	2000	Marketing	5683
46.	Marketing	683			Classics	1700	Microbiology	5167
47.							Mol Bio & Biochem	5000
48.							Biological Sciences	4560
49.							Physiology	3600
50.							Comparative Literature	3336
51.							Ecology	2986
52.							Spanish & Portuguese	2000
53.							Classics	1700
54.							Mathematics	1640
55.							French & Italian	500

SUMMARY AND RECOMMENDATIONS

Federal policy on science and technology and the nourishment of research in these particular intellectual and academic sectors within universities are intimately linked. The extraordinary contribution made by universities to the national interest through research in science and technology is frequently seriously underestimated. Within this context, the role of graduate students is neglected; federal support of graduate students in science and technology falls short of what is optimum in terms of national priorities. For these reasons the mechanism for funding these graduate students merit the most serious and thoughtful consideration.

In addition to support costs of graduate students, it should be emphasized that in a research university a scientist is expected to spend one-half of his or her time engaged in research. Therefore, one-half of that scientist's salary is paid by the university to achieve research results which serve the society and thus the national interest. To these costs must be added laboratories, equipment, libraries and library acquisitions, construction of new facilities, and other essential ingredients needed for the conduct of research. This research could not be conducted without the graduate students; it is an indispensable linkage. Except for its reputation which is, indeed, priceless but non-fungible into dollars, the university is not the primary beneficiary from its support of the costs to nourish science and technology, but rather the society-at-large. These expenditures are the university's gift to the national interest. Without this contribution, the outlook at the national level would be devastating.

The case study of the support mechanisms for science and technology at Northwestern University underscores not only the importance of, but also the need for, additional federal funding. The support provided by the University has reached a level which severely strains its resources. If the trend is not reversed, the contribution of Northwestern University will be jeopardized. What is happening at Northwestern can readily be extrapolated to other research universities.

For these reasons, I offer the following recommendations:

1) As the study of highest achievers suggests, thoughtful consideration must be given to develop incentives for the best and brightest undergraduates to enter research and teaching careers in science and technology.

2) The decline in traineeships must be reversed so that quality departments, determined by a review of scholarly peers, can provide graduate student support which, at this time, is in a precarious state.

3) After appropriate review by scholarly panels, federal agencies must develop a more favorable policy of including more graduate students on project grants as research assistants, thus enabling principal investigators to conduct their research effectively while training a new generation of scientists. Currently, the item to support graduate students as research assistants is the first one to be eliminated from the proposed budget of a principal investigator by the program officer. Even though graduate students constitute at least one-half of the human resources engaged in the successful conduct of research, they are too often considered as stepchildren in this vital process. Federal support should promote, not discourage, the indispensable linkage between research and graduate education. The magnitude of support should be increased without a diminution of quality of the student who is the recipient of that support.

4) Stability in federal support is essential if universities are to plan intelligently in their contribution to faculty and graduate students engaged in research. Abrupt changes in policy produce chaos and waste. Unexpectedly losing a traineeship, for example, can mean hundreds of thousands of dollars of unforeseen demands for the support of graduate students who are in mid-course and need funding to complete their studies. Such sudden demands place an incredible burden on scarce university resources. The better policy is to provide a base for support comprised of a mix of portable fellowships based on merit, training grants, and research assistantships associated with project grants.

5) The financial burden on universities to support research as their contribution to the society at large is straining their resources to the breaking point. This burden must be eased, if only modestly. In my judgment, if science and technology were properly funded in terms of the national interest and priorities, universities could resolve most of the support issues in the non-science academic areas.

6) Thoughtful steps must be taken to develop policies on funding which will attract an increasing number of minorities and women into graduate study in science and technology.

7) Consideration should be given to utilize programs effectively which are need-based, in particular work/study, as a support mechanism for graduate students in science and technology.

APPENDIX A

1984/85

BREAKDOWN IN GRADUATE SCHOOL SOURCES AND TYPES OF FINANCIAL SUPPORT

Wilson Jones
Form 30-8

			1	2	3	4	5	6	7	8
			University Funds				Non-University Funds			
			Service	Non-service			Service	Non-Service		
1	University Fellowship	(a)		1077429 47						
2	University scholarship	(a)		396788 50						
3	GRAT/S	(a)	446960 50							
4	T.A. - allocated funds	(a)	1716234 05							
5	T.A. - work-study	(a)	77908 31				181786 05			
6	Departmental funds	(b)	285670 34							
7	Government Fellowship	(b)						150488 63		
8	Government Traineeship	(b)						127343 45		
9	Research Asst - govt grant	(b)					908403 44			
10	Research Asst - private	(b)					82910 20			
11	US private or corp. fellow	(b)						230580 99		
12	Foreign private or govt fellow	(b)						222338 32		
13	Endowed fellowship	(a)		89044 01						
14	Grant or scholar not thru U	(a/b)						47590 50		
15	Continuing Education	(b)					101082 66			
16	Personal funds	(b)						912733 50		
17	Loans	(a)						590461 —		
18	Other	(b)						18710 —		
19	TOTALS		2526773 20	1563261 98	=4090035 18		1274182 35	2300246 39	=3574428 74	
20										
21	(a)	Source of information – Graduate School records								
22										
23	(b)	Source of information – Departmental records								
24										
25										
26										

APPENDIX B

SUMMARY: SOURCES OF FUNDING BY SCHOOL
Fall Quarter, 1984/1985

Wilson Jones
Form 30-8

	University Funds	Non-University Funds	Self-Support
College of Arts & Science	1777359 74	899761 66	351737 50
School of Speech	456430 55	159098 35	38574 -
Technological Institute	1103345 91	739424 42	413044 -
School of Education	84955 85	35460 30	110801 50
School of Music	22334 -	2573 -	23522 -
School of Management	274959 -	36417 -	33181 -
Chicago Campus	246037 23	171473 51	128178 50

Mr. Fuqua. Thank you very much, Dr. Ver Steeg, for a very comprehensive report.

STATEMENT OF DR. F. KARL WILLENBROCK, CECIL H. GREEN PROFESSOR OF ENGINEERING, SOUTHERN METHODIST UNIVERSITY, DALLAS, TX

Dr. Willenbrock. Thank you, Mr. Chairman.

First of all I'd like to start my remarks by commending both you and the members of this committee for first your attention to science policy on the long view and then in particular for your attention to this particular aspect of science policy of the question of the human resources involved. As indicated, I will focus most of my remarks on the engineering area, since this is where I have the most information and knowledge and also you've heard very complete overall views from some of the previous members of this panel.

In the interesting assignment that this committee is undertaking of looking 40 years ahead and also looking 40 years back I think it is interesting to note that what I considered the farsightedness of the policymakers of 40 years ago really had a tremendously positive effect on the science and engineering in the United States. The combination of Federal actions like the GI bill of rights and then the—as a result of the Bush Report and other legislation at that time, the investment in Federal funding and research in universities has really, in my estimation, made the—been one of the leading factors in making the United States such a world leader in science and technology as it is today.

So, therefore, I think we're talking in essence about a success story, but I think it is also valuable to look at some of the reasons for that success and also to see if there aren't ways we can make success even more successful. And what I'd like to do is point out a few areas in which I think that we can do—make some improvement in how the Federal Government interacts with the university community and also with the related industrial community.

First of all, if we look at the question of research funding and its affect on education and the training of scientists and engineers it is clear that the primary impact is at the Ph.D. level and I'd like to point out that there is considerably less impact at the master's degree level and even less at the undergraduate level. If I look now at the case of engineers we have the situation that roughly two-thirds of the engineers don't go beyond the baccalaureate level and maybe even a lot more of that don't go beyond a master's degree level, and so the question is how—what could we do about the quality and effectiveness of the educational experience of this major part of the technological work force has available to it?

My feeling here is that we could—we could make our training at both the M.S. and undergraduate level a lot more effective than it is now and I think that's the opportunity that we really ought to exploit.

Let me give you some of the indicators of why I think this part of the educational system needs some fixing. First of all if you look at engineering practice there have been some very significant changes in how it is carried out in leading industries today. I'd say there are relatively slow changes in how undergraduate education and

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master's level education is carried out. Another fact that remains important, the data from the accrediting agency still indicates that the quality of the undergraduate education in the United States in engineering is not improving and indeed the problems associated with shortages of faculty, shortages of facilities and equipment and shortages of U.S. graduate students have all taken their toll. The other indicator that I think is important is the fact that there are many new fields of engineering in which there is not a rapid increase in undergraduate and master degree level programs. I'd like to point out particularly the biotechnology area where in essence it's very clear that what is needed now is a type of engineer. An engineer who knows as much about biology as the chemical engineer knows about chemistry. This is clearly where things ought to go. There are a lot of chemical engineers with this need, but yet the resources to make that happen just aren't there. And it seems to me that here is an area where we could strengthen our overall enterprise very significantly by some appropriate investments.

One comment that I hear you make, Mr. Chairman, if I may pick on you, is that there is some question about whether engineers are not in bad shape because you don't hear complaints from industrial employees of engineers. And I'd like to comment on that if I may.

First of all before World War II, I can assure you the engineers that came out were a lot worse than they were after World War II and before—in that period we didn't hear industrial employees complain about the quality of their engineers either. However, when they got better trained engineers they did not use them very effectively.

Another point that I think is worth making is that the quality of the engineers and students concentrating in engineering these days is higher than it has ever been before and if you look at education as sort of an evaluative process we're starting off with a very high value and you're adding a certain amount to it, so the results are good. What I would like to do is direct your attention to what would happen if we took these very superior students and gave them a superior educational experience. I think we could take on the world that way and I'd like to urge that as a way of looking at things. The question is how do you fix it and all I can say is the mechanisms to fix it are all there. NFS has got the legislative mandate, in my estimation. It has the prestige within the academic community to actually have some of the most creative faculty members in the United States spend some time on the question of improving the educational techniques and the educational process and I'd like to—and what is needed, it seems to me, is the decision to go that way and of course the resources to back up that decision.

Well, turning now to another point, I'd like to talk about how we handle fields of science and technology and particularly technology where the major activity is not in the university sector. And if you look at areas like computers, and so forth, and some of the very rapidly moving technologies it is clear that the major effort is carried out, not in the academic community, and one of the questions gets to be, how do you prevent a gap between current—state-of-the-art current practice and what goes on in the academic—in academic programs. It seems to me this is a very important aspect of the quality because a serious gap there has deleterious affects not only on the faculty and the students, but also on the ultimate employers of those students.

This is not an easy area to worry about or there aren't some quick fixes here, but in general it is recognized that if you want to transfer knowledge the best way to do it is within people's heads, and so therefore, the knowledge transfer from the universities to the industrial and governmental world in science and technology is pretty good since the students—that's where they're employed. However, the inverse process does not go on that well and I think it would be very desirable to have Government policies which essentially encourage that reverse flow. One of the prime examples of such a policy, in my estimation, is the new program of the National Science Foundation on Engineering Research Centers, where they effectively force the interrelationship of the industrial community and the academic community for those who wish to apply for that program. The overwhelming response that that program had when it was announced, which was typical of NSF programs, they get an overwhelming response from the academic community and I think this is both a sign of good management at NSF and also an indication of how hard up some of the academic institutions are, and it could well be that we have an over amount of influence on the part of Federal funding agencies. But, the point I'd like to make here is that the very strong response indicated that there was a resonant—it hit a resonant note in both the scientific and the industrial communities. And I think that is a very important part of it because here is an indication that the industrial community does wish to work closely with the academic community. And the academic community has a lot to gain out of this close tie. And it is a major way—it is a very important step, in my estimation, of closing the gap in some of these areas where the major thrust is in the nonacademic community.

I'd now like to turn to another aspect and direct your attention to fields of science and technology which are not closely associated with a major Federal mission agency. There are many fields of science, the most vigorous fields of science and technology are those in which there is a major amount of funding available and in today's world the dominance of the defense community is very evident. But, now what about those areas of science and technology which are not closely associated with a major funding agency? What about their vigor? And some may say, well, you should put your resources where the quality is, but it is also true that the quality goes to where the money is available because if you look at the life in the university world, without any external support it can be pretty grim. The faculty member who has no external support usually ends up with very little secretarial support, practically no equipment or facilities, no support for his graduate students and also no travel fund. So, therefore, the incentives for a faculty member to gain external support are very strong and it seems to me that we should be concerned about those areas of science and technology where there isn't an active Federal agency carrying out, which funds external research.

There was a very interesting example recently in manufacturing engineering. IBM has really made a major change in the engineering world simply by announcing a program of $50 million of support for requests for proposals in manufacturing and engineering. Well, it is interesting that this is an area which was—attempts to cover this area by some of the Federal agencies, and I happen to be familiar with some of the work that NSF has done in this area in the past and also the small amount that the National Bureau of Standards did, simply wasn't able to get this area off the ground. And it was a major effort, major grant by the IBM, which really has made a significant difference and is making a significant difference, I should say, in this particular field.

But, you may ask yourself, what about other fields of science and technology and particularly technology in which there isn't a major corporation like IBM who has both the foresight and the resources to make a major change? I think there are those areas that we—that I think need attention, which do not get attention because there is—the funding available for research in universities follows so strongly the funding patterns of the mission agencies. I don't have a quick fix on that one, unfortunately, but I do think it is not in the best interest of the country to let our science and technology be dominated by that type—by the funding patterns which presently exist.

Let me now turn to another area which has been touched on briefly by two members of this—two speakers on this panel. This relates to the question of academic employment and here I would like to talk about the ability of the universities and particularly the colleges of engineering to attract the top rank U.S. students to full-time graduate work and work full-time academic careers. I think it is clear that increasingly the university sector is dependent, if you will, on foreign born graduate students and foreign born Ph.D.'s to keep its ranks in some sort of shape. The overall statistics, I feel, have a tendency to wash out some of the very specific needs. If you look downstream and say what would happen if over a long period there isn't a change in the present situation and I think you could predict that one of the things that could happen would be the universities, if they are not able to attract top-rank people into the academic community and into faculty careers in essence the role of the university will change in a significant way. In other words they will no longer be very active participants in the knowledge generation function or the research function and they will turn—their activities will be focused in the—in teaching only.

Now, this is certainly one possibility. Other countries don't use the combination of research and teaching that we do, however, I think that most educators in science and engineering would feel that that would be a very serious weakening of the university structure, if indeed we're not able to make that situation change. Now, I realize that this varies from field to field and as I look ahead I think it is very difficult for the universities to be competitive for the top-rank people, with the industrial community, when the industrial community has got a strong R&D bent and has the combination of facilities, financial rewards and a lot of other techniques for making positions very attractive there. I don't mean to say that it isn't in the best interest of the United States to have good scientists and engineers in industry, but I also am totally convinced that it is essential for the universities to be able to attract top-rank people, and if the only faculty candidates available to them are foreign-born Ph.D.'s I think this has a very important implication for the future of our academic institutions.

Well, let me just summarize by saying that I would like to call the attention of the committee to the desirability, if you will, of explicit Federal support for what I call research experimentation and innovation in engineering and science undergraduate and master degree level education. I also feel, as I've indicated, that we need to pay attention to those fields of science and technology which do not happen to coincide with the fields of major Federal mission agency and finally I do think we need to spend some time thinking about how best we can insure that the academic institutions of this country continue to attract the top level people, who are characterized by their operations during the past 40 years and make sure that they do so for the next 40.

Thank you very much, Mr. Chairman.

Mr. FUQUA. Thank you very much, Dr. Willenbrock.

[The prepared statement of Dr. Willenbrock follows:]

Testimony
for Science Policy Task Force
Committee on Science and Technology
U.S. House of Representatives
"Scientists and Engineers: Supply and Demand"

by

F. Karl Willenbrock
Cecil H. Green Professor of Engineering
Southern Methodist University

July 10, 1985

My name is Karl Willenbrock and I hold the Cecil H. Green Professor of Engineering chair at Southern Methodist University. My remarks today will be focused primarily on engineers and to a lesser extent on physical scientists.

The nation's economic vigor and quality of life, as well as military security, are strongly dependent on the number and quality of the engineers and scientists which the U.S. has available both now and in the future. Thus, the health and well-being of the system which educates American youth in engineering and science and enables the practicing engineer and scientist to stay at the forefront of rapidly developing fields of science and technology is a crucial part of the nation's science policy.

The present leadership position of the U.S. in most fields of science and technology indicates that the U.S. does have in being an effective system for educating scientists and engineers. However, the quickening pace of technological developments and the increasing capability of other nations to use existing and emerging technologies in both the commercial and military arenas make a Congressional examination of the supply and demand of engineers and scientists both timely and appropriate.

Effectiveness of Government Programs

In the post World War II era, there were two federal programs which contributed directly to the present U.S. strength in science and technology. One was the GI Bill of Rights which enabled returning veterans to undertake extensive educational programs and effectively established a federal role in support of graduate fellowships and traineeships in science and engineering. The second was the funding of research in science and engineering at universities. The Office of Naval Research and then other federal agencies such as the National Science Foundation, the National Institutes of Health as well as other federal mission agencies became substantial supporters of University-based research in science and engineering. The combined effect of these two far-righted public policies was to increase both the number and the quality of Americans with the scientific and engineering skills needed by the nation to attain its present global leadership in science and technology.

However, although we can be proud of the achievements of these past forty years, it behooves the Congress to look ahead and seek to display comparable wisdom and foresight in shaping national science policy for the next forty years. To do so, let's examine some of the specific characteristics of the present practices and examine their effect on the nation's future supply of scientists and engineers.

Funding Mechanisms

The federal support of science and engineering at universities has focused on research not on education. The result has been greatly strengthened academic research capability in science and engineering. While the focus on research is appropriate for the federal mission agencies, the NSF also has

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legislative authority to support science and engineering education.

The federal support to education in science and engineering has been less successful. Because of the intimate relation of academic research to graduate education at the Ph.D. level, research support has strengthened Ph.D. programs. However, at the undergraduate and Master degree level, federal funding has had less effect. Yet such programs are of great importance to the nation's scientific and technological enterprise.

The physical sciences and engineering should be considered separately. The student who wishes to pursue a career in the sciences should go on to the Ph.D. level and, if the career goal is research, a post-doctoral period is usually advisable. In engineering, approximately two-thirds of the nation's 1.5 million engineers do not continue their formal education beyond the baccalaureate. Thus, the strengthening of undergraduate and MS-level programs in engineering could increase the overall U.S. engineering capability.

The barriers to such improvement are two-fold: first the motivation of creative faculty members to undertake educational research and experimentation and second the resources to do so. With respect to faculty motivation, the NSF has the key. There is great prestige in the academic world associated with being the principal investigator on NSF-sponsored projects. If the NSF initiated programs of a continuing nature which were directed toward research in engineering education, some of the nation's most creative faculty members would devote time and effort to making engineering education at the undergraduate and MS-levels more substantive and effective than it is at present.

Do engineering education programs need improvement even though the employers of engineers, primarily industrial companies, do not frequently complain about the quality of new engineering graduates? My response is twofold. First, the employers of pre-World War II engineers did not complain about the ability of their newly hired engineers; but they made good use of the much better-educated post-World War II engineers. Second, the quality of students concentrating in engineering now is higher than it has ever been. What would the result be if these superior students were being given a superior educational experience? My prediction is that the long term result would be a major gain in U.S. international technological competitiveness.

What kind of improvements should be made in engineering education? THe rate of change in engineering education has been relatively slow despite rapid changes in engineering practice. While some would ascribe this fact to out-of-date faculty members, I believe that the more fundamental reason is that schools of engineering do not have the discretionary resources necessary to support new educational developments. Engineering schools operate without adequate resources to fill existing faculty vacancies, to attract U.S. graduate students, and to maintain up-to-date instructional and research equipment and facilities. Their ability to undertake new educational programs is vanishingly small.

For example, there is a clear future need for a new type of process engineer - one who is as well-versed in modern biology as chemical engineers are in chemistry. To educate such biochemical engineers, curricula need to be developed, textbooks need to be written, laboratory experiments need to be organized. The faculty capability to do these tasks exists; the motivation and resources are not available.

Quality and Relevance of Science and Engineering Education

The quality of the faculty is the primary determinant in the quality and relevance of the educational programs available at universities. Federal support plays a crucial role in faculty members' ability to stay at the forefront of their disciplines. However, there are a number of fields of engineering and a few in the sciences in which most new knowledge is not generated in the universities but rather in industrial or governmental laboratories. In such fields, a significant gap can develop between the state-of-the-art and the content of academic programs. The deleterious effects of such gaps on students, faculty, and the employers of the graduates are obvious.

In this context, the increasing interest and support by the industrial community in university education is a most desirable development. Better techniques for the transfer of new knowledge back to the academic community need to be developed. Since it is generally recognized that the most efficient mechanism for knowledge transfer is by people, it would be most desirable for industrial and governmental engineers and scientists to become participants in the educational process at universities. While there are many examples of such participation now, federal programs which encourage such participation are particularly valuable. The NSF's new program in support of Engineering Research Centers which required the university requesting funding to demonstrate active industrial participation is a prime example of a desirable policy.

However, another type of problem arises in the fields of engineering and science in which there is relatively little academic activity. I should like to cite as an example manufacturing engineering, a field in which current academic programs with a few exceptions are weak. IBM has recently caused a major increase in the available university-based programs by making sizable grants to a number of academic institutions. Why was such an effort by a private company necessary to invigorate this field of engineering? What about other technical fields in which there is not a corporation with the vision and resources of IBM?

The explanation lies in the skewed nature of federal research support to science and engineering. Most of this support comes from the federal mission agencies. Thus, it reflects those fields of engineering and science which relate most strongly to the specific agency's mission. There are a number of fields of engineering and science which are not closely aligned to the missions of a major federal agency which funds external research. Some examples are chemical processing, building and highway construction, vehicular transportation other than aerospace, fire safety, metallurgical processing, and machine tools. The rate of technological progress in these fields varies tremendously. In some it is strong; in others, the technology used has not undergone much change in many decades.

Is it good government science policy for the nation's system for educating its future scientists and engineers to be so strongly influenced by the current funding pattern of the federal mission agencies? At present, the Department of Defense funding clearly dominates a major portion of the nation's system for educating its future scientists and engineers. While it is certainly desirable for the universities to help provide the knowledge base and also the human resources needed to maintain U.S. leadership in military technology, what about those areas of technology which contribute primarily to the strength of the domestic economy or the quality of life in our country? While there are many obvious connections between military and civilian technologies - aerospace being the classical example - there clearly are technologies in which the needs of the federal mission agencies and the private economy do not overlap.

In effect, the current federal policy is to ignore such areas. The adverse effect of this policy was evident in the slow development in the U.S. of robotics and automated manufacturing systems. Although the importance of developing the hardware and software necessary to automate manufacturing processes was clearly recognized to staff members in both the NSF and the National Bureau of Standards in the early 1970's, the ability to support a program of adequate scale was lacking. Now the U.S. is operating in a catch-up position to other highly industrialized countries.

Academic Employment

Returning now to the issue of faculty quality, there is a problem of increasing importance to the future strength of the U.S. science and technology community. The facts that U.S. schools of engineering are not able to fill their faculty vacancies and are increasingly dependent on foreign-born Ph.D.'s to fill faculty positions, that fewer U.S. engineering undergraduates are interested in academic careers, and that universities are decreasingly able to maintain well-equipped instructional and research laboratories in science and engineering indicate that the universities have some chronic problems which most of them have not been successful in meeting. The most serious of these problems is the inability of colleges of engineering to attract the most academically able U.S. engineering graduates to academic careers.

If top-quality engineers and scientists can no longer be attracted to university faculty positions, the nature of graduate education in the U.S. will undergo a fundamental change. The research or knowledge-generation function would no longer be an academic activity. The university would then focus on teaching while research would be a function of other organizations. The separation of teaching and research in science and engineering would weaken both enterprises. While some of the leading universities are still able to attract the unusually able engineers and scientists to their faculties, other universities are already moving in the direction of becoming teaching only institutions.

Conclusions

After World War II far-sighted public policies produced a GI Bill of Rights and a program of federal investment in university-based research. Some of the elements of a far-sighted science policy for the mid-80's and beyond follow: First, an explicit recognition of the desirability of federal support for research, experimentation, and innovation in engineering and science undergraduate and MS-level education. The fear that such a policy would result in federal control of the content of the education is as unfounded as the fear that the federal government would control the content of federally supported academic research.

Second, a mechanism for supporting educational and research developments in fields of technology and science which do not happen to coincide with the fields of current concern of the major federal mission agencies which fund external research. Implicit in such a policy would be the recognition that progress in science and technology is in the best interest of both the public and private sectors. The entire nation is clearly dependent on the nation's educational system to produce a steady and continuing supply of scientists and engineers. The number of individuals involved and their choice of fields of specialty should be shaped by the scientific and technological opportunities available as well as a broad perception of both national and global needs.

Third, means of enabling the schools of engineering and science to attract some of the nation's top-ranking engineers and scientists to faculty positions or to active participation in the nation's science and engineering educational system. Implicit in this policy is the recognition that the university faculties need to include top-rank engineers and scientists if they are to continue to supply the quality and quantity of engineers and scientists needed to maintain U.S. technological leadership.

Thank you Mr. Chairman, for giving me this opportunity to appear before the Science Policy Task Force. I will be happy to respond to questions as best I can.

Mr. **Fuqua**. Dr. Ver Steeg, you gave a case study in your presentation about Northwestern funding. Do you think that's rather typical throughout the other universities?

Dr. **Ver Steeg**. Well, it may be more typical of the private institution than the public institution, so that certainly has to be taken into account. But, I think it's rather typical of, I'll call it the middle range institutions. I think there are certain institutions which, for example, research assistants will be—and Federal funding will be much greater if you look down the list of such. Stanford is probably a good example of that. I think they probably have a different configuration. Not on teaching assistants, but on research assistants. But, I think for the great majority of research universities, we are rather typical.

Mr. **Fuqua**. Dr. Moore, you—it appears that supply and demand in the marketplace kind of controls to a certain extent the amount of people that are going into the various sciences. One that has had a record increase in one of the charts someone had was computer science, engineering, yet, when I look at the chart, viewgraph on No. 5 of your testimony, it looks like about 61 percent or 62 percent is going into either medical science or biological science, which are somewhat comparable, a very small percent going into engineering, math, computer sciences and all other sciences—only about probably 15, 18 percent. How does—is that reflective of the marketplace or is it demand for medical science and biological science is much greater than the other?

Dr. **Moore**. Well, that chart shows a distribution of Federal obligations for——

Mr. **Fuqua**. Fellowships and traineeships.

Dr. **Moore** [continuing]. Fellowships and training grants and so it is the result of the process of allocation of funds for those areas. Now, the relationship between that process and the market I couldn't comment on. I don't know how that would work, but I would say that it is, in some sense, indirectly affected by that, but also reflected by a number of other priorities that are placed upon the allocation of funds.

Mr. **Fuqua**. Yes, Dr. Hill.

Dr. **Hill**. If I may comment on that. I would think that that distribution is largely toward the medical sciences and biological sciences. A function of NIH is longstanding activities in supporting students in postdoctoral fellows in those particular areas. As you know they started their program in the late forties and it has increased a lot.

Mr. **Fuqua**. That's a very good explanation and I think that probably does account for that.

Dr. Hill, we understand that the NIH predoctoral and postdoctoral programs have been very successful in also adjusting to the work force for supply and demand. What do you attribute that success to and would it apply to say, programs such as in the NSF?

Dr. **Hill**. Well, I think I should point out that all of the fellowships, traineeships, any kind of educational funds given to any trainee by the NIH is done so after peer review, and clearly by peer review you select the best students in the Nation and you start funding students based on rank. The best students get funded first and the next level and so forth. Of course funds are sufficiently scarce that you support only the upper 10 to 20th percentile of the applicants in a given year. So, I think the success of the system is based upon the way the system selects the trainees.

Mr. Fuqua. Dr. Ver Steeg and Dr. Willenbrock, you both mentioned about the difficulty—well not difficulty maybe, but the importance of attracting high achievers or high quality students into these programs. Now, we have the National Merit Scholar Program and in some cases they're recruited maybe not as much as football and other athletes, but they are being recruited. Is that program making it possible to attract because you haven't identified the ones that you feel would be very desirable to have, does that make it easier and then many of them have scholarships or other means of support for these merit scholars? Is that working?

Dr. Ver Steeg. I would say that there is more involved than just the scholarship itself. That is, it is the career pattern and that if they see a career pattern, that is the first class student sees a career pattern in which the outlook looks rather bleak, then it discourages that student. Let me give you a very specific example. We brought to—attracted—I guess is a better word, to Northwestern, a person in neurobiology and physiology who had in fact was a superb student from Duke, taken some work at the University of Texas, came to Northwestern University. She passed a brillant oral examination. She decided at that point to go and get a degree in masters of management because her principal investigator, who is a very distinguished woman, had had such difficulty in getting funding, and she just didn't want to go through that pattern. And I think that's a—not an unrepresentative example. This was a superb student.

Dr. Willenbrock. If I may comment, Mr. Chairman, if you look at the engineering area, the number of students coming in and the quality of the students is superb. Our problem is how you hold onto them after they get the baccalaureate degree, and then after they get the Ph.D., how do you hold onto them. The competition is definitely tough. So the—that's where I perceive the need to is. And I think what we are really looking for is some other ways that universities can make their faculty careers more attractive. The numbers—some of the faculty salary numbers that John Moore quoted you were a little bit low for engineering, in so far as I'm concerned. Typical assistant professors in, say the Big Ten schools and so forth, are starting at $35,000 to $38,000 a year, but still that doesn't—that's not the whole story. The whole story is what is the career pattern going to be like? Is there going to be a desperate difficulty in funding? How do I get the facilities and equipment I need? All those other issues that are a very important part of the career decision.

Mr. Fuqua. Well, let me followup. Should the Federal Government, through our national policy and through the NSF and the NIH and other relevant agencies, should we try to regulate the supply or demand of science and engineers or target certain educational programs for the future?

Dr. Willenbrock. I don't think you could regulate, but I certainly think you can distribute carrots around in such a way to make

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things happen if you look at the response of the university sector, and so forth, to the various programs that have been announced: the IBM program I referred to in manufacturing and engineering; the Engineering Research Center's program; the DOD program on funding equipment and facilities. You'll see that in a number of those areas the university community is very responsive, is one way of putting it. You can say it is almost lip sought, is another way. But, the—so, I think the interplay of the Government programs, the interplay with the industrial sector and the academic community, this is a mixture. It's a combination of the events and policies which can be put together—I hope, can be put together in such a way that we really do make the academic career pattern such that the highest achievers will see this as the way to go.

Mr. FUQUA. But, the main thrust is can we direct that from a national point of view? Can we have a manpower management agency or attempt to try to do something of that type?

Dr. VER STEEG. I don't beleive you can do that. I really don't. I think you simply have to, in a coordinated effort as universities, Federal funding, sort of an outside climate and outside environment have to, in effect, say "Look, we are interested in these very bright people, and we want to see them make a major contribution, and this is a way that makes it possible for them." Let me give one example. Artificial intelligence is a science that is just beginning to emerge and it is spattered all over the place at the moment in terms of trying to bring people together, but there is a very, very bright young man, 25 years old, who was, in fact, at Caltech, now at the Institute for Advanced Study. What brought that young man into that field, and why did he leave Caltech to go to the Institute, and so on. There are all kinds of factors involved, but he is a brillant person and the innovation that he has can be translated into very important national purpose and—anyway I don't think it can be done by regulation.

Mr. FUQUA. Yes, Dr. Hill and Dr. Moore.

Dr. HILL. Yes, I wanted to share with you the attitudes of the National Needs Committee. For 10 years we've often had people asking us, mainly from NIH, what are the critical shortage areas within the NIH? Who should we be training? And we've occasionally found that there may be a need that we expect in some areas like biostatistics, epidemiology, and so forth, but largely we feel that the peer review system that I referred to earlier chooses the very best people, and the very best people go into the areas of need, and in fact they create the areas of need, for the future by their own research. Opening up a research area can lead to a whole new development. Every one of the areas, or at least the major areas in biotechnology was the result of some sound basic research of high quality that could be applied. So, I think that it is almost impossible. I agree with Dr. Ver Steeg, to pick with assurance the priorities of the future in a given research area.

Mr. FUQUA. Dr. Moore.

Dr. MOORE. Just a couple of comments. Going back to Professor Willenbrock's point about the salaries, I think it is important to bear in mind that you're absolutely right about what's going on in the very top research universities so far as salaries and engineering are concerned. But, of course, there are several hundred others that we also have to bear in mind, and the data that I presented were averages for all, based on a recent survey of all of them. And so I think that needs to be considered. But, I would also like to agree with the previous two commentators on the impossibility of a national scientific manpower management system of some kind. Let me just give you an example and Professor Willenbrock might want to comment on this also. You know one of the shortages in the field—in faculty that I mentioned in my prepared remarks is in computer science and in certain fields of engineering. You might look at it as being the field of, shall we say, computational science. Now, there are tremendous excesses of enrollments, excesses in the sense that the demand is far greater than the planned capacity for these subjects in a number of universities. And the question is whether that is a temporary phenomena or not. And I don't think anybody has the answer to that question right now. If a manpower management organization were in place it would have a big problem in trying to decide whether to plunge in with a lot of resource commitments to that field where the outcome will not even be known for 7 to 10 years. And so I think that's an example of the kind of difficulty that such a proposal would mean.

Mr. MINETA. Mr. Chairman.

Mr. FUQUA. Certainly.

Mr. MINETA. I'm just wondering whether or not as we talk about the benefit to the students, what about institutionally or what about geographically? What's the spread? Are the top 10 schools in engineering getting all the money? Are the top 10 schools in medicine getting all the money? Are the top 10 schools in whatever field getting all the money? And I'm wondering, you know, it's great to talk about the need of the students and everything else, but what about geographically? Is there a good spread across the country? The NIGMS [National Institute of General Medical Sciences], in terms of general medical sciences, seems to get concentrated at the top medical schools, but there are some other fine schools that may not be, for whatever reason, be rated in the top five or whatever, they seem to go begging. They don't get the grants and so—you said the students go where the money goes. But, hopefully quality goes also, not just bodies.

Dr. HILL. If I could comment on that, once again the peer review decides the factors of where the money goes. You're quite right, the top 10 medical schools in the Nation, medical centers may have the lion's share of the research funds from the NIH, but that's judged on the basis of peer review. Now, in the training, which we're really talking about here today, there are two kinds of NIH support—predoctoral training, for example. A training grant to an institution and an individual fellowship. The top institutions in the United States get the training grants that go to the institutions. And indeed they are congregated in the elite schools in the Nation. However, by peer review again individual students from institutions that are not generally acknowledged to be in the top 10, 20 in the Nation are given to students in schools there. So, the fellowships can take care of the training needs of—under the direction of qualified preceptors, faculty members in institutions that are not in those top 20. Training grants do indeed go to the top. But, we feel generally that we can't argue with the quality. Geography we have not dealt with.

Mr. MINETA. Is there a way to deal with it?

Dr. HILL. Geography? No, sir. Not from my viewpoint as a biochemist.

Mr. MINETA. Doesn't that disparity get wider though? The rich get richer.

Dr. HILL. Yes indeed. I think there is an element of that in it.

Dr. VER STEEG. May I just respond one—I just want to respond along one line. One of our characteristics of American society—in fact, I'm a historian by training, not a scientist—is that, particularly since the Second World War, it has a long history of a decentralization of talent. And if you look at the universities, indeed, that you would attend if you were going to an *X* discipline in, say 1945, versus 1985, there would be a vast difference. And one can take all types of examples: UCLA, for example, and so on, which was hardly existing in 1945 and now has an extraordinary research enterprise. So, there are, in fact, institutions that are emerging and as they are peer reviewed they do begin to attract more funding, but I do think there is a way, and it's kind of a natural thing that it should occur.

Let me give you an example. If there are 20 training grants in the M.D.-Ph.D programs and you're trying to break the magic circle with your particular institution you have a difficult time. You not only have to prove you're as good. You have to prove you're maybe a third better than the last of those training grants, because they have program in training. You have to prove that you're not only at that level, but a little bit better in order to break it because there is a limited amount of money. If there were a bit more money that would make a difference. But, it takes a little while for an institution to get to that—to where it will be reviewed favorably. In fact, it may be reviewed favorably because the other grants, however, in process, you will miss. That happens.

Mr. MINETA. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Walgren.

Mr. WALGREN. Thank you, Mr. Chairman.

There are a number of thoughts and I wanted to ask Dr. Moore, on this chart No. 5, where you talk about the distribution of Federal obligations for fellowships and traineeships and training grants, who is funding all the social sciences in that chart? There is 18 percent, much larger than the physical sciences and even that with all other sciences combined, except for the medical and the biological. NSF certainly isn't doing that. Who is the source of most of that funding? Did somebody just—is there a one-word answer to that?

Dr. MOORE. I don't have it, if there is one. And I would—I'm afraid, Mr. Walgren, I would have to look that up. I'm not sure where that money comes from. But, it's not NSF. That much I do know.

Mr. WALGREN. You indicate, Dr. Moore, that there is this trend of decline in that kind of support of fellowships, traineeships and training grants, and an increase in the teaching assistants. Would that reflect simply increasing financial stress on the university where they're having to press more people into teaching at that point, as opposed to a conscience decision on the part of any overall health of what's going on?

Dr. MOORE. I think the decline is largely—the decline in the share of fellowships and traineeships is large because of NIH declines in fellowships and traineeships available. The other factor may well be involved too, but I think the primary cause in that change in the distribution, which is what that is meant to show, is the decline in NIH. As I mentioned earlier, NSF fellowships have grown at least over the last 3 to 4 years in numbers and amounts, but NIH has declined.

Mr. WALGREN. As I understand it, the peer review would be most concentrated in the principal investigator award in that you are really judging a research project almost simply by its comparative merits and therefore, if you fund by principal investigator award you really heighten the intensity of peer review, whereas if you have things like fellowships, which go to individuals you would not necessarily—you could have a more distributive function in that. Traineeships certainly so. If we—are we, in increasing the numbers of principal investigators awards and decreasing the traineeships and the fellowships that could be used more distributively, are we concentrating things even further on a peer review basis?

Dr. MOORE. Let me just comment, as far as the NSF's programs are concerned. As you know, the graduate fellowships are awarded on the basis of merit to the pool of applicants, and the awardees are free to choose any institution they wish to go to. Both of those things, by the way, are in the Act. In the NSF Act.

Mr. WALGREN. Both of those are?

Dr. MOORE. In the NSF Act, specified in the act itself. Now, what happens, in fact, if they tend to be attracted to the universities where the most interesting research programs are going on. And I haven't done the calculations, but my guess is that if we did do the calculations we'd find out that the distribution of the fellows, NSF fellows, by institution is not much different from the distribution of research assistants supported on NSF grants by institutions, that's my guess. And so I would say it's part of the same general matter and not—I'm not sure that very much would be gained by the reemphasizing fellowships at the expense of research assistantships.

Mr. WALGREN. What lies behind your noting that graduate students in computer science attracted only $75,000 a year in total Federal support prior to 1983?

Dr. MOORE. It's an amazing fact. I was really struck by that when I found it out, but they—there just wasn't much support given to computer scientists until very recently. Apparently, as I interpret the statistics. Now, it may be that there is something in the statistics that is not visable on the surface, but it's a very interesting fact.

Mr. WALGREN. Any thoughts on why that was missed so completely?

Dr. WILLENBROCK. If I may comment on that. There is some of the data that comes out, has some peculiarities which relate to the fact that a lot of computers were supported as part of electrical engineering department, computer engineering, some different terminology was used and so I think there is a—you can get some statistical phenomena in there that don't make that much sense. The

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categorization is not a very precise one because frankly, the fields overlap so much that you can't tell the difference in many cases anyway and what in one university would be called computer science, in another university is computer engineering and could be a part of an electrical engineering department.

Mr. **Walgren**. With engineering graduates from the college level getting salaries almost equal to what professors would get at universities, obviously there is a problem there. Have any of the universities experimented with paying those selected professions—those selected disciplines more on a teaching basis and what's been—has that been favorably received in those universities or has it created a problem?

Dr. **Hill**. May I make a comment on that? Certainly within the medical profession we've had that problem for years. You cannot hire a professor of surgery for the same amount that you can hire a professor of biochemistry and the marketplace has certainly filled the faculties of the schools of medicine with good people.

Dr. **Willenbrock**. Yes, I think there have been a number of responses. A couple of years ago the University of California system essentially set up different salary ranges for faculty members in engineering versus faculty members in business, versus faculty members in other departments. So, therefore—but, on the other hand, as you can imagine that does create strains within the university system. However, the fact is that the market does dominate and if you don't respond you can end up with a very first-rank school really missing out. I happen to be on the advisory committee for the College of Engineering at Berkeley and at one time they—before this change in policy they had 20 faculty slots and they could only fill 11 of them. Well, if a top-ranking school can't fill its slots you know that there is something wrong with the system and they had to make that change, in my estimation, in order to survive, but they certainly have survived. So, it has been necessary, and actually a number of schools have been very responsive to it, and some of the numbers I was quoting on assistant professor's salaries just indicates that that is the way it has worked in some of the areas that are dominated by opportunities in the industrial sector.

Mr. **Walgren**. Mr. Reid.

Mr. **Reid**. Thank you. I'd like to, just before we have to run and vote, to get your comments. Last year, in the paper that you presented to us, Mr. Moore, you said that 24 percent of full-time graduate student degrees were awarded to foreign students. Why? First of all let me say it's not all bad. We're trying to get more foreign student scholarships and things of that nature because of the tremendous educational drive the Soviet Union has is one example. But, why? Why are we having such a large percentage?

Dr. **Moore**. Well, let me first say I don't have a full explanation. But, I would think first of all that our educational system is so strong and offers such great opportunities to these people that——

Mr. **Reid**. To everybody except our own students it seems.

Dr. **Moore**. Well, that's the second part of the point. The real question in my mind is why it is that more of our own citizens are not going into graduate work. And I——

Mr. **Reid**. See, I'm not concerned about the number of foreign graduate students. I think that's good. It's the number of American graduate students that's very bad. You know there is nothing wrong with the number of foreign students, it's the percentage that bothers me. Anyone have any idea why we don't have more American graduate students in the sciences?

Dr. **Moore**. I think, as we've been talking here a little bit, that the career opportunities that are open to bright young students as they finish their baccalaureates have been increasingly steering them in directions other than graduate school.

Mr. **Reid**. Next question. I'm sorry. I'm sorry we're so rushed for time here.

Dr. **Hill**. It depends on the field. I think, if I'm not mistaken, engineering graduate schools largely have a very large foreign student enrollment because the American students are not going. But, in other fields that is not the case. In many of the biomedical basic sciences the-—we have 90 plus percent students from the United States in those programs. Those programs, of course, are basic biotechnology and things that are quite important for the future and realized by the students.

Dr. **Moore**. That is quite right. I think the figure—most recent figure for Ph.D.'s in engineering is 55 percent—over 50 percent foreign students, but——

Mr. **Reid**. So, this 24 percent figure is——

Dr. **Hill**. That's an average.

Mr. **Reid** [continuing.] Is an average and in engineering it's over 50 percent.

Dr. **Hill**. Right; in the sciences the figure is about 20 percent, if I remember correctly, so the weighting—the figures are weighted very heavily by enrollments in science as opposed to engineering. But the engineering figure is very large.

Dr. **Willenbrock**. If I may speak to that, I was interested in another part of Mr. Moore's data, and that is that the number of M.S.'s is going up and the number of Ph.D's is going down in some of these areas, and I think the answer is that to many—in many areas the question of whether a Ph.D. is a cost-effective degree is really under—is the issue. If the facilities—if you need the facilities and equipment and they aren't in the universities, they are in industry, does it make a lot of sense to spend 3 or 4 years getting a Ph.D. degree? Why don't you get a master's degree and then come to work for this company which has better facilities? That indeed is the case. That's the situation and the people who make those judgments I think are making correct judgments from their own individual standpoint,. I do think, from the institutional standpoint it points to the problem that the universities have of trying to fix that situation so that they're not denuded of the top people.

Mr. **Reid**. We're going to have to go vote. We'll be in recess for probably about 10 more minutes.

[Whereupon, a brief recess was taken.]

Mr. **Fuqua**. Mr. Lujan.

Mr. **Lujan**. Thank you, Mr. Chairman. I only have a couple of questions. They're short questions, but there are maybe not short answers. I don't know.

Particularly, I guess from the receiver end of the spectrum, is the system working pretty well? I guess that's a question that we have to answer in science policy. The followup question will be, if it's not working pretty well, how do we change it. Dr. Ver Steeg?

Dr. **Ver Steeg.** Yes, I think that the ingredients of the system are there. And I think my colleague here, Mr. Willenbrock, has emphasized that. So, I think that's an answer. My own testimony, as you can remember was, we have really had a decline in traineeships, and I think that's an unused area or not sufficiently utilized and interestingly enough it's not utilized outside, really of NIH. And it isn't utilized at all in technology, and it seems to me that it is a possibility. The third thing, as a matter of fact, that is underutilized is certain kinds of what are now called campus-based, need-based things, such as work study, which I think are also underutilized, but I think as a totality the ingredients are there.

Dr. **Hill.** Well, I'd just like to follow up on that briefly. Although I'm here representing the National Academy of Sciences, a giver, if you will, I am a user. I have a research grant and a director of training grant and so maybe you'll allow me to comment. The various mechanisms for training that are in place today are excellent and the mix should be maintained. I think there is a place for research grants for training students and postdoctoral fellows. There's a place for fellowships. There is a place for training grants. There is a place for teaching assistantships and so forth, but we've got to have a proper mix of all of these to allow the university to utilize, to the best advantage of the students, all possible training mechanisms. So, I think we've got a series of good mechanisms. They should be used together, but they're slowly being eroded away.

Dr. **Moore.** Just a couple of brief comments. Generally I would certainly agree with what has been said here, although we don't, at NSF, have much in the way of traineeships. I do think it is important to maintain the close ties between research and education. I think that's extremely important to the development of competent research personnel. And having them working with the best people doing research is essential to the program, so that I think it should be maintained without any question.

One place, I think, where the system could be improved is in paperwork.

Mr. **Lujan.** In what?

Dr. **Moore.** In paperwork required of investigators at institutions who are seeking support. This is I'm sure not any news to anyone, but I think that can be a serious problem. One of the things that affects what you might call the quality of academic life diverts research effort from its real purpose and makes life uncomfortable for the researchers.

Mr. **Lujan.** No one said we would have to put more money in.

Dr. **Hill.** Oh, yes.

Mr. **Lujan.** Did you just happen to forget that or——

Dr. **Hill.** When I commented that the number of trainees is being eroded away it's because of the lack of funding.

Mr. **Lujan.** OK. Does that system, you know, if it is working fairly well, putting out what we need as far as the manpower needs in the country are, do people generally go into those things that have the need? You said there is an overabundance of occupational type of people——

Dr. MOORE. The opposite. That's a very real shortage. Yes.

Mr. LUJAN. But, I mean getting out of the flow the proper mix that industry requires.

Dr. VER STEEG. I think that's hard to answer. I don't think we've studied that with great care. I think because you don't hear the comment it doesn't necessarily mean that that's what is occurring. It's just like the question with regard to are we getting, in fact, the top people? Not enough study had—the study that I have brought to your attention does some of that, but it hasn't done it, let's say, currently for the creative person. The same thing is true in the marketplace. We really do not follow those studies out as well as we should, and I think we have a lack of information. Because we don't hear squawking at the time I think. Moreover, I think when you project everybody's difficulty, it seems to me when they start projecting, as an historian we never project because we just don't have that competence. Economists project and are always wrong. So——

Mr. LUJAN. There was an article the other day that said we ought to get the weatherman to predict the economy and the economist to predict the weather and they'd be right about the same percentage they are now.

Dr. VER STEEG. I didn't mean to belabor my colleagues the economists, but I did want to say though if we've got the mix and we've got the quality students and those quality students become quality researchers we're going to be all right. It's when they don't see a career ahead that is valuable. The specific example I gave of that one student who is absolutely the top rank moving away from research into management. Now, somebody is going to get a very good manager. I'm not suggesting that, but here was a person fully equipped, being trained in a first-class operation and moving away. That's discouraging. And it's that kind of thing for the future, it seems to me, which is something that has to be—we have to be concerned about.

Mr. LUJAN. Let me focus the question in a little different way now. I guess one of the things that bothers me and others, as I talk to many of my colleagues, because maybe 10 of my colleagues come from places that are favored by the distribution system today and 425 do not, so I guess 425 to 10 we would find are dissatisfied with the distribution system of everything going to the big universities and the rest left behind. You think we ought to change that system? You think that we would be better off, as a country, by doing things different? The peer review is good, but one of the things that I find, and I'll use the—something that I always get on my soapbox on in the fusion business, those that propose large machines in the fusion business are in control of that program in DOE and that's where all the money is going and none of it to alternative ways of doing that. And that seems to be what happens. You know you've got peer review, you've got those same ones because they're the eminent ones in the country, so you get those—them doing the distribution and a lot of us are rather concerned with that distribution. I'd like for you to address that and see if there is some concern on your part.

Dr. **Willenbrock**. I'll take the first one at bat on that one, Mr. Lujan. The situation is that you are going to get concentrations for a variety of reasons: in some cases as a critical size in order to get a good effort going—that's practically every academic area I know of has got a critical size problem. Another issue is in many areas and particularly ones that I'm familiar with, the equipment and facilities are tremendously important. If you look at something like electronics, and you look at very large-scale integrated circuits, there are three institutions in the United States which are well equipped to carry on state-of-the-art research in that particular field and you can say, well, isn't that pretty narrow and the answer is that that's where a tremendous amount of the activity is right now.

Mr. **Lujan**. Yes; but if I could just make a comment on that. When you put in the big computers, where did they go? They went to the top 10. So, the rich get richer.

Dr. **Willenbrock**. Yes. That's—I'm saying there are lots of things that make it happen that way. Not only the peer review system, but the concentration that you need to have a full-scale effort and also the facilities make it a difficulty. I think it's sort of a mixture of problems, I think, that are associated with that and I don't think there is any single answer. One of the ways that I would hope we could get a bit more dispersion is through the interrelationship in some of the engineering areas between the industrial companies that are at the forefront of particular fields and the universities and I think to that extent you can help spread the wealth a bit. But, I don't think you can start out with a policy of trying to spread the wealth. I think what you can do is start with a policy of trying to encourage growth of quality in a number of institutions. I think that ought to be the way—I think that ought to be the underlying method for proceeding.

Mr. **Lujan**. Instead of saying share the wealth, spread the wealth, how about spreading the excellence.

Dr. **Willenbrock**. OK fine, they're spreading the excellence, improving quality in a variety of places and there are a variety of ways to do it.

Dr. **Hill**. I think it's a very difficult thing to change the nature of a university and bring it from a low-rank in a given academic area to a very high rank. But, I think it has been done. I think it is constantly happening. I think that one of the—well, for example I'll name a State. Texas. The University of Texas system has had the wealth to do it. And I think that other States that would aspire to bring their State universities up have to put funds behind it. I don't know of any other reason or any other way. Of course, you also have to have citizens of the community—you're talking about a State I guess that would be the geographical unit of concern—have to be concerned about it and want to give their money toward it. And you have to have that local leadership, as far as I can tell. In my State of North Carolina we don't have particularly outstanding educational statistics, but we've got some good universities and we have had people in our Government who want to do something for science. Thus the North Carolina School of Science and Mathematics—I'm sure this committee may have heard of in the past—for high school students was created. So, you've got to have a local leadership, I think, to bring your State institution up and it's not a very fast process.

In the interim I think that you're going to have to put your Federal funds where the best brainpower is and if that means the top 10 universities I think it should be maintained that way.

Mr. LUJAN. Or you can move the brainpower. We did that, for example, with Los Alamos. There was a boy's school over there and in one decision like that made it a laboratory.

Dr. MOORE. I'll just make a couple of points here. First of all I think I'm the only economist on this panel, so I've got to do something about that remark. I would just say that I bet both the weatherman and the economist would think they could do the other guy's job better. Whether that's true or not is another matter. I've never engaged in forecasting myself, however.

I would agree with the previous comment in the sense that movement is possible within the rankings of universities and there are some States now where important things are going on in that respect. And I think—but, it does take a long time. It's not something that happens quickly or overnight. It takes years. And I don't think—well, I won't say that. The other point I guess I would make is that the facilities matter is a difficult problem. I mean, after all, if you have four supercomputer centers you've got to put them in four discrete sites and then the discussion becomes how you choose those four sites, but those sites are going to be favored in some way or another. And there is only one Fermilab and that's out there at Batavia, IL, and that can't be—it can't be anywhere else, so that's a problem.

On the other hand if you look at the support of individual researchers, which I think NIH and also NSF do a lot of, that's a little bit different. There an institution can, by trying to attract good faculty, over a period of time, build up its support for individual research grants and I think one of the consequences of that is that eventually that will lead to the placement of facilities there that previously might have gone elsewhere. There is a kind of chicken and egg problem there I know, and I don't know how you deal with that chicken and egg problem. But, I think there is a distinction to be drawn between the facilities matter and the matter of supporting individual research.

Mr. LUJAN. Without taking a lot of time, just rather quickly, should we aim for distribution or should we continue to favor concentration?

Mr. WILLENBROCK. Let me just—I'll be No. 1 on that one. The NSF mandate, of course, is to promote the strength of science and engineering for the Nation as a whole. And I think in carrying out that mandate we must take into account the excellence of the research and the strength of the base that we are creating. I think that primarily that implies that we look at the excellence of the proposals that we receive. Beyond that, once we've settled that issue then I think there is room for at least some discussion on the second one.

Mr. LUJAN. Is that how you missed that bright person going into management, because she didn't happen to be at one of those?

Dr. VER STEEG. Pardon?

Mr. **Lujan**. Because she didn't happen to be at one of those lucky enough where the grants are concentrated.

Dr. **Ver Steeg**. Well, actually she was in a very good program with a first-class person that she was working with, but the person had difficulty in getting funding over a sustained period of time, and in a certain sense Northwestern is one of those sort of gray point institutions.

Mr. **Lujan**. Northwestern ranks 20th in NSF funding.

Dr. **Ver Steeg**. That's right. And so we're in kind of a breakpoint and we feel it. We definitely feel it and there are such things, if you'll remember a couple of decades ago, of centers promoting areas that are on these break points from centers of excellence. And that program, I don't know how one would rate the results, but it certainly, if you want to, not spread the wealth so much, but you want to raise the quality of excellence in institutions that have the capacity for doing it, one of the ways to do it is to have an infusion in particular areas where you can do things.

Dr. **Willenbrock**. If I may comment on it, I think the—I don't think the policy of equal distribution would make sense. On the other hand I think if you design the system so it is permeable to institutions breaking into the—increasing their quality and breaking into a top rank, that's the way the system ought to go.

Mr. **Mineta**. Just picking upon this whole issue of distribution let me ask about not only the geographical. Dr. Hill, you mentioned the MARC Program. I had a chance to speak to the MARC Program at the national convention in San Jose earlier this year. What about minorities? What are we doing in terms of getting minority and women into the graduate programs, research areas. You know, we're doing some in terms of the ADAMHA Program, we're doing some, I guess, in terms of principal investigators, but what are we doing really through NIGMS and all of the other programs that are available to get minorities and women into the programs?

Dr. **Hill**. Well, the MARC Program, which you already mentioned you're obviously are familiar with. We have made a study of it. It will come out in our October report of our national needs committee. Briefly stated there are excellent examples of students who have come to the MARC Program and have gone on to postgraduate work. Now, most of the students going on go into profession degree programs, like medicine, dentistry and so forth, but we do have some that are going into science. Now, you might say that's not enough. There's not enough going into Ph.D programs. I submit it's going to be a slow and difficult process and I don't think the funds spent on the MARC Program are ill spent if we only get a dozen students out of the first cohort of classes going through a few dozen. So, I think we stand behind the MARC Program and similar kinds of programs, in answer to your question.

With respect to women, now that again varies by field. I don't know that you can generalize, but let me say it's my feeling in the biological sciences that women are rapidly approaching 50 percent of the students and trainees in our programs. In my own department we have 50 percent women. The women are coming. They're competing beautifully for NSF predoctoral fellowships and they're taken in the institutions they want. Some of our best applicants to our department out of 180 people we take a dozen a year for predoctoral work and the women are doing beautifully. I say let the natural forces leave them alone and they'll survive very well.

Dr. **Ver Steeg**. May I respond here? I think on the women that's correct. I think the situation though on minorities is scandalous, simply scandalous and I don't have any other words for it. I think we have not done nearly enough to try to attract—first of all for them to get the right preparation for minority students, get them ready for in fact science and technology careers and then help them once they get there. I really think no one can take very much pride in what's been done.

Mr. **Mineta**. Any solution?

Dr. **Ver Steeg**. Well, I'll give you one thing that we've started to do in the Big 10, we call it committee on institutional cooperation. We have a program in which we attract people from all over the country. We give about 40 fellowships. Part of those fellowships are supported by foundations, part of it by the universities, none by Federal Government. Of that group they are superior candidates, but the one problem we have as a matter of fact is in the science and engineering area. Partly because in fact they're not coming out of the baccalaureate degree programs. So, it's something that starts way back in seventh and eighth grade and I know there are some people here, but I'm on the Research Roundtable working group, which is trying to work on the matter of identifying talent and one of the areas that we've addressed or want to address is the very area that you discuss, that is the underrepresented minority group. But, there is just no question nationally that it is scandalous.

Mr. **Mineta**. Are the women you referred to as a group, Dr. Hill, to the extent that they're also in the program are they also being employed in the marketplace to that extent as well?

Dr. **Hill**. Yes indeed, I think so. I think the new faculties hires that you see annually and that we monitor in our committee, there are a lot of women going into those. The day has passed when you can find a science department that is totally male. You could 10 years ago and you probably still can today, but our faculty has 3 women out of 18. We had one in 1930 and the second hire wasn't made probably until 19——

Mr. **Mineta**. The one of the three still there?

Dr. **Hill**. No.

Mr. **Mineta**. Let me, if I might, just change directions just a little bit. It seems to me in the academic field it's publish or perish. How does that impact upon principal or the research assistants who are with—principal investigators who are doing research at a university. Are they really getting the kind of training that is preparing them professionally or are they being used, you know, as the "go-fors" for that program and not really getting that much out of it?

Dr. **Hill**. Watching—knowing several faculty in my own institution as well as other institutions I'd say that probably scientists and academics have the same spectrum of personality as the general population. You're going to find some people who are very selfish, but by and large I think they are more rare in science than you might expect. I don't think too many students are being misused by their mentors, at least in the fields that I know something about. I would be the first to admit that some students have better

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training environments than other students, but students are pretty resilient. They're also pretty restive, the good ones and they get along well. I don't think their mentors mistreat them. As a matter of fact a mentor that neglects his students might be doing the students a service because the students learn to fend for themselves, which they must do in real life anyway. So, it's a complex question.

Dr. MOORE. Even crass materialists like economists share in their research results, so my experience is consistent with yours. And I would come back to the point that the opportunities that graduate students get by being research assistants to outstanding scientists and engineers in their research programs, the access to equipment, the access to their experience and knowledge is extremely important to their own development. I would say that almost, even if they don't share in the publication credits, but I think on the whole they probably do share in those credits.

Dr. WILLENBROCK. I would agree. I had a few more comments. I'd also point out that students can vote with their feet. If there is a faculty member that doesn't do a good job for them he doesn't end up with as many graduate students working for him. So, it means that the system is somewhat corrective.

Mr. MINETA. But, don't the students again, going back to your original thesis, gravitate where the money is?

Dr. WILLENBROCK. Yes, they're going to gravitate where the action is and where the interesting work is going on, but if that's a very exploitive atmosphere I don't think —I think that could be a change. I don't really think that's a very significant problem. I think you could find particular cases, but not as a general rule is that an issue.

Mr. MINETA. What about terms of broadness of training? Or is there a tendency to overspecialize?

Dr. VER STEEG. I don't know if that really is the word. I think in traineeships, as someone on the panel, I think, pointed out, there is a little more opportunity for a student to make a choice. If there is a mismatch, I think it was your comment, Mr. Hill, if there is a mismatch it's very easy for that student, in fact, to be accommodated where there, in fact, will be a match. Whereas in the project grants and the students supported by those project grants there is, obviously, some very strong tendency for a student to work in the area of the project grant. And that is in fact why he serves as a research assistant. I don't know if that means much about specialization, however. I don't really think at this moment it is too over specialized, but we ought to be careful about that. I think as Professor Willenbrock has mentioned, there are areas in which these interdisciplinary tendencies are occurring and he mentioned, I believe, biochemistry and —I'm sorry, chemistry and chemical engineering and the life sciences. And there is a focus that chemical engineers have to be more aware of than most of them are.

Dr. HILL. Well, I think your question has to be looked at and inspected just a little bit. If you would say knowing chemistry and very little biology is overspecialization, well, perhaps so. But, I think you can turn around and say that if you have a little bit of knowledge of chemistry, a little bit of knowledge of biology, a little bit of knowledge of this area within each of them, you might know nothing about a lot of things. And that would be called interdisci-

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plinary training. I spoke last week to one of the people you will have tomorrow from industry and he said that he is going to tell you this that what industry wants, is a well-rounded scientist in a given discipline—a well-rounded chemist, a well-rounded biochemist, a well-rounded pharmacologist. And if they are well grounded in one discipline and know how to do science, they are wonderfully prepared to do the kinds of things that industry wants them to do. So, I wouldn't call that overspecialization even though a person might not have any education in the name of interdisciplinary work. You need well-rounded, well-trained people in their basic discipline.

Mr. **MINETA**. As we let the marketplace sort of be the determinant, how do we make sure that quality somehow is also a factor in all of this?

Dr. **HILL**. Quality is a factor.

Mr. **MINETA**. Isn't a factor?

Dr. **HILL**. No, it must be a factor. If quality is not evident in some activity the funds will not follow it, so I think that's the theory of due process again.

Dr. **VER STEEG**. We—people here realize this is not a perfect system. Democracy has its problems and in fact peer review has its problems and no one should claim that it is a perfect system. It's probably the best system that we can develop. It isn't perfect. And there are going to be crevices. There are people who are going to slip through. The bright person, it seems to me, who is going in an all new different direction sometimes does have some difficulty in getting funding at a particular moment in time, whether it is a student or whether it is a faculty member

Dr. **WILLENBROCK**. If I might comment on the quality issue. The custodians of the quality are the faculty members. Now—and that why I made a point in my testimony of the importance of getting the—attracting the quality people into faculty positions so that indeed they can maintain the quality for the success of people in the field.

Dr. **MOORE**. I'll just add one remark, and that is that it seems to me that industry demands quality at least as strongly as academics. And I've heard it said, and I emphasize, I've heard it said that there may be developing a little difficulty in that the best quality engineering Ph.D's are now going to industry instead of into academic careers, which if true is something to be concerned about.

Mr. **WALGREN**. Would the gentleman yield?

Mr. **MINETA**. Absolutely.

Mr. **WALGREN**. I'm kind of bothered by the total unquestioning acceptance of a peer focus on merit and a dismissal of the distributive function, particularly with respect to the NSF, because although I'm sure if you focus on merit you—that's one way of doing the things the NSF is supposed to do, but that's not the only way. And in a way when someone just said the peer review system is the best system that's been developed, in a sense it is the only system that's developed because we have run right to that by and large. And I'm concerned that there is sort of a self-interest of those who can deem themselves meritorious to keep patting each other on the back about how meritorious we all are and be operating a system

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that leaves out substantial parts of the fabric of the society that we should be picking up.

Now, the thing that I wanted to focus on was Dr. Moore gave a little tracing of the mandate of the NSF, in which it was to strengthen science as a whole. And that, therefore, you went to merit and you really didn't even get to the distributive function unless you really took care of this other emphasis almost completely and when you're only funding 20 percent of the science and engineering graduates with a Federal program. Anyway you're obviously never going to get beyond the most meritorious and yet if you look at the act the act doesn't even mention the word "merit" with respect to the NSF. It doesn't even appear. And in fact, the purpose of the NSF is to, and I quote, and it's almost a sole purpose in the organic act, is to "strengthen scientific research potential." Now, you can do that by focusing on merit, but that's a very narrow and rather exclusive approach to strengthening potential. And moreover, in the charter of the NSF it specifically underlines the distributive function by saying, "In exercising this authority and discharging the functions it shall be an objective," now, I don't say it is the exclusive objective, but no one said merit was the exclusive objective either, "it shall be an objective of the Foundation to strengthen research and education throughout the United States and to avoid undue concentration of such research." Now, isn't that at conflict with the approach that all you gentlemen have been taking?

Dr. MOORE. I'm not sure it's really a conflict, Mr. Walgren, by the way to answer your question about the source of funding for social sciences, it's mostly the Department of Education, about 80 percent comes out of the Department of Education.

I'm not sure it's a conflict and maybe I missed—didn't speak my—didn't express myself very clearly on that matter. I think what is essential is that somehow we get an understanding of what—of how to carry out the mandate which you have quoted and of course that exactly is the mandate.

Mr. WALGREN. And what we're aimed at is potential.

Dr. MOORE. Yes, right.

Mr. WALGREN. That's what we're aimed at. We're aimed at scientific potential.

Dr. MOORE. That's right. And I would certainly not—could not disagree that there is room for us to discuss exactly what that means in terms of what kinds of work and what criteria are used in deciding on our research allocations. I would say that I think that the results that we have seen in terms of the scientific excellence in the United States of the system that has been in operation have been good. Now, one can never say it's the best that could possibly have been obtained. We don't know what that would have been, but the results have been very good. And before we make any drastic changes in the system we need to be careful. And think the thing through as carefully as possible.

Mr. WALGREN. Again those words, "to strengthen scientific research potential."

Dr. MOORE. Right.

Mr. WALGREN. That's the purpose of all this money. And to—I think as lawyers you have to assume a broader, rather than a narrower interpretation of those words. One of the things that really troubles me is that in all my limited exposure to the NSF I have never seen a discipline program—not program, but a disciplined development of how you reach that objective that we could talk about. All of a sudden everybody ran to some kind of peer review and we wind up with certainly a concentration There is a debate over whether it is an undue concentration. It's certainly a concentration and it would seem to me that a not narrow reading of that word "potential" really directs you into a far more outreached and far more developmental approach than I have seen reflected in the present.

Dr. HILL. Well, you know, your concern about distribution of funds, say from the NSF or NIH by geographical region, is that what you're really concerned about?

Mr. WALGREN. Well, I don't know if it means just by geographic region. Apparently the liberal arts college did a study recently which showed them essentially not participating at all in any NSF funds. They are the total undergraduate experience of perhaps 20 percent of the people who become the best Ph.D. candidates and they zero out when it comes to any support with respect to facilities. And they zeroed out on a whole—on several ranges of basic support in the natural sciences.

Dr. HILL. I understand then what you're speaking about. My view of this has always been that there are limited funds to accomplish something for the citizens of this country. We do research because we think we will get some results that will be beneficial to all. Since the funds are limited I would think that you would want to find the best people in the United States, irrespective of where they are, to do the necessary research, to come to some conclusions that will help you solve some kind of problem. AIDS is among us as a disease, a new disease, the statistics on that that you probably read are rather frightening to say the least and what the future brings, if we don't know how to cure it, could be quite disastrous. I submit that I would not want to put AIDS research funds into any other institution except that institution that had the best people possible to study AIDS and come up with the answer. By the same token, training. I would not want to put funds into training programs that were not staffed by the best faculty possible that you could find. Now, if you had unlimited funds and you could use them for geographical distribution certainly that's good and well. But of course these small institutions that you say are without funds are not without their impact on science and science education. They provide a tremendous population of students to go on to the major research centers and university training centers for further training.

Mr. WALGREN. And you would think that because they do that that they would be touched by our efforts to increase the potential and yet they are untouched.

Dr. HILL. What do you mean by touched?

Mr. WALGREN. I mean they don't participate in any of the benefit that is distributed by the NSF. As I say in the instrumentation of facilities the liberal arts colleges in this frame, but we're educating just those people who you said, go on to make such a big impact and they have absolutely zero contact with our programs to

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increase the potential of science in this country. And that seems to me to be a gapping absence.

Mr. MINETA. Could I reclaim my time since I only have 1 minute left of the 3 minutes that I was given?

Mr. WALGREN. I'm sorry.

Mr. MINETA. And I'd like to follow up on this. I'm just wondering, isn't this some kind of intellectual snobbery that say we know where the best are. And I don't know whether I'm really going to be giving a fair example, but you gave the example, Dr. Hill, of AIDS as being very important. I think I know of a case where a very qualified person was involved as part of a team dealing with the virus on AIDS and I bet that university doesn't have one NIGMS grant. The University of Tennessee with Dr. Correra right there as a biochemist, and I don't think they have one grant from the National Institute of General Medical Sciences, and she is one of those who has worked on that and I don't think I'm overstating that or mistating the facts. And yet someone has said, well, the University of Tennessee, you know, what do they know down there in the Smokey Mountains? We'll give it to Harvard, we'll give it to Stanford, we'll give it to the University of Chicago, the University of Texas, wherever.

Dr. HILL. Well, sir, I guess we're coming in the education of scientists and engineers to the question of what the appropriate balance is. The other point I would make is with regard to the question of patting each other on the conclusion, the realization that science is elitist. I'm afraid it is and so is education to a certain extent.

Mr. MINETA. And I come from a very proud school in that regard, UC-Berkeley.

Dr. HILL. Yes; and I got my education at lesser institutions by anybody's ranking, but I don't know that's not prevented me from interacting and doing what I needed to do in the world to become a scientist. And you know, your comments about the University of Tennessee, surely the people I know of at Memphis campus have research funds. Knoxville, there are some.

Mr. MINETA. Knoxville is not bad.

Dr. MOORE. Let me—if I could make just a couple of comments here. Mr. Walgren, it isn't quite true that the colleges are totally untouched by NSF. There are some programs. Now, we can discuss the magnitude of them, but there is a College Science Instrumentation Program research at predominantly undergraduate institutions and another one or two that do provide some funding to 4-year colleges. Now, I agree it is small. We'll not——

Mr. WALGREN. And it was, I think, probably parts of our country in that excellence and the question is, how do you distribute that excellence. And to me that leads me back to the developmental role of NSF. Now, you can say science is elitist and I will give you that, but that doesn't change the role of NSF as attempting to balance that elitism in some constructive way. And Lord knows NSF is little enough compared to the total. And what I don't see is I don't see an emphasis on the developmental side of the mandate that the Congress set out when it created the NSF. And that word potential is loaded with development, and I've never seen the NSF really get its teeth into that part of it. Instead, I've seen it be totally preoccupied with simply awarding the most meritorious grants and pat itself on the back for how many Nobel laureates they have had contact with over the years. And that's not good enough. Again the democratic society where we're saying no special shakes, but equal access to opportunities. And I think that that has a, you know, is really a foundation on which this country is built, has been made great and that does have a distributive developmental kind of critera to it.

Dr. **HILL**. But don't you think the educational system at the university level has equal opportunity of access for students? I've always felt it did. I know I was a student. I didn't have access to Harvard and I wasn't smart enough or rich enough, but you know, I had an alternative and so I don't feel handicapped. I think the NSF should enhance it, but getting back to this point of Mr. Walgren's a little bit. I think the NSF historically has done many things to enhance the potential for science in this Nation. For example, they've had a very expensive effort to look at the teaching of mathematics, the teaching of science, the teaching of biology, the teaching by field, put a lot of funds in that. They had many reports. They published books, the books were adopted by teaching programs throughout the United States. I think that's the way to enhance the potential of science. And I would submit perhaps if specialized funds were forthcoming for special kinds of programs like that and others that we could certainly enhance the potential of science in this country through the National Science Foundation.

Mr. **WILLENBROCK**. I think the statement you just made, that was just made which related to equal access is exactly the right way to look at it. I think equal access is important and I think we ought to look at that on an individual basis, also on an insitutional basis. I think we better make sure that we have a permeable system so that institutions can emerge and develop into higher quality programs and so forth and I think that openness is really a very key part and I think this is the direction that NSF could make an effort which would be responsive to the concept of looking for potential. And I think it has in the past, but I think it's a tough job to do, but I think that certainly ought to be the general direction of policy.

Mr. **MINETA**. Let me ask, in the—after students get their graduate degrees, especially foreign born, who are here under our immigration laws, as I recall they have to return back to their native country, I think for a minimum of 2 years before they can reapply to come back in after they've gotten—after they've been here for educational purposes. Do we lose in any way either in the industrial sector or in the academic community by forcing, forcing these people back to their native countries?

Dr. **WILLENBROCK**. I don't believe that is a present—that is proposed in some of the legislation which was—on some of the bills before the Congress. I don't believe that it is essential for people to go back for 2 years if they can get an employer to back them and so I don't think they——

Mr. **MINETA**. If they're here on a Fulbright aren't you required to go back or what—or any of these kinds of exchange programs or—aren't you required if you're here on some kind of a——

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Dr. WILLENBROCK. All I can say is an awful lot of foreign Ph.D.'s become immediate members of faculties and I don't quite know how they do it, but they do it pretty regularly.

Mr. MINETA. Maybe they get married to someone.

Dr. WILLENBROCK. Some of them are unmarried I guess.

Dr. VER STEEG. The Fulbright is special, but that is a very small program compared to the whole.

Mr. MINETA. Right, that's true.

Dr. VER STEEG. And so I think you're correct on that, but not on, in fact, the other.

Mr. MINETA. I think, Dr. Willenbrock, you're right. I think it was in that proposed legislation about the 2 years, yes. OK.

Dr. WILLENBROCK. Naturally a lot of academic institutions and industries are fighting that legislated proposal.

Mr. MINETA. I am, too.

Dr. VER STEEG. Can I say one thing about the democratization, if you wish, or potential. When you think of how many scientists have come out of the City College of New York, you know it's really quite staggering and most of those, after they emerged, began in fact to be supported by some kind of Federal agency, including NSF, but the mix of the eduational system I think is what Dr. Hill and others are relying upon to allow this talent to emerge, this potential to emerge and what I think you're focusing on is after an emergency has taken place, but on an individual-to-individual basis I think the emergence does occur. And on the business of elitism or whatever it is, I would suspect if one took a sociological profile of the scientists who have in fact become important because of the national interest and because of their own reputations, I don't think they come from an elitist group at all. I think that it would be a very broad spectrum of background that you would discover.

Mr. WALGREN. No; I wouldn't think that, but once the professional has defined itself then it has coalesced into a group which could be described as elitist. Their origins are not elitist.

Dr. VER STEEG. There are certain aura effects that occur. There's no question about that. If an institution develops and becomes—if everybody goes to a place like Harvard there is an aura effect, there's no question about that.

Mr. WALGREN. Let me ask this, speaking again of the NSF and particularly this sort of goes to Dr. Moore then. The—I would have to assume that there are very meritorious and, in fact, exciting research, basic research potential in the private sector as well as the universities. And there is nothing in the charter that focuses you on universities. And yet almost all the NSF's attention goes to university-based research. Now admittedly we rely on the universities to do a great chunk of the basic research in the country, but it is striking that none is awarded outside the university system. Now, that must mean that you're using some criteria other than just merit, because certainly in the Bell Labs or someplace like that there are some very exciting instrumentation that has got some real merit potential and would compete and not compete with what's being done in many of the universities. But somehow or other all the moneys have gone to universities. Now, I would conclude from that that something other than merit is driving that exclusion?

Dr. **Moore**. Well, not quite all the money has gone to universities. Almost all the funds, I agree. And we receive proposals from outside of the university community from time to time, but I don't think that the numbers are large. I don't——

Mr. **Walgren**. Can I just interrupt?

Dr. **Moore**. Let me make one other point in connection with the potential issue that you mentioned and have been focusing on. You know, you look at that potential in a number of different ways. And one way is to say that our research potential as a nation depends on the knowledge base that we have. And I think it does. I don't think that there is any question about that. And that's not the only element it depends upon, but that's certainly the one very important element. And I think that the system that has evolved, again it's not perfect, has done quite a good job of generating a very good knowledge base because of the way that it works. Now, as I say that's not the only factor to take into consideration. In the end, the potential depends on the people that you develop to do the work and the encouragement that is given to people with the potential to do that research. I think the system hasn't worked too badly in that respect either.

Mr. **Walgren**. But are we in the danger of being in a position of saying well, we're just going to continue doing it this way because we've always done it that way?

Dr. **Moore**. Well, no, I certainly don't think we are in that position. I think we are evaluating it and thinking about it in a variety of context and I think process—I certainly agree wholeheartedly that we should not continue to do something simply because that's the way it's been done. And that we ought to be taking a look at it.

Mr. **Walgren**. I guess my point is that I think that you can see other than merit forces operating in the direction, particular of NSF funds. In fact, someone facetiously said it's not the National Science Foundation, it's the "University Science Foundation". And I can understand it developing that way and I can understand it predominently developing that way, but I think we have to be honest with ourselves about the fact that those forces are operating and just as they have sort of focused on the universities to the exclusion of some nonprofit and some private sector research that would have competed on the merits, I think we could also say that it is focused on some universities to the exclusion of others that probably could have competed on the merits. And to say that that doesn't happen is to, I think, avoid the reality that we're faced with and not drive ourselves to making things better and to improving the role that NSF can play.

Dr. **Moore**. By the way I was just reminded of one point that I had forgotten to mention in connection with the review. And that is that the Director of the Foundation has established a committee to look into that issue exactly. It's chaired by Norm Hackerman formerly from Rice, of course.

Mr. **Walgren**. Chaired by whom?

Dr. **Moore**. Norman Hackerman.

Dr. **Hill**. Well, can I follow up just a little bit on the other groups not getting certain kinds of funds. I think the science estab-

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lishment of the United States depends very heavily on regional national laboratories. The NIH in the health field is a tremendous organization. Now, they are directly funded through their own budget in their intramural program and they do not need to compete for research and they compete for training, but they do not need to compete for research funds. And if you look at the laboratories in the Department of Agriculture, why should they compete for NSF funds when the Department of Agriculture supports them? So I think that the Congress, in its wisdom, has created a great structure for different organizations to do the research and training in the United States and there is no need for a lot of these groups, nonuniversity based, to compete for these funds.

Mr. **Walgren**. But I would come back though to say that there is a need for the NSF to be measuring how well they're doing and if it is in that charter then to be filling in that gap. And not walking away from it and saying we're just following the most meritorious pursuit of leading edge basic research. And trusting that everything good will happen with respect to potential, which is really a very different goal and to which this concept of funding the leading edge of basic research is only one method of enhancing that potential and a limited method at that.

Well, I'm sorry. I guess I'm going on and it's really not up to me to be making statements and I think I ought to say on behalf of the task force as a whole we appreciate your having come today and all the effort that went into preparing your testimony. We do appreciate your being a resource to us and hope that ultimately the record will reflect the factual data particularly that you've laid out and the obvious weight that should be given to the kinds of concerns that you've presented. So, we do appreciate your being a resource to the Committee, and with me we would go on forever kind of back and forth and that's not too helpful. So, thank you very much again and we will then adjourn and convene at 9:30 tomorrow morning.

[Whereupon, at 12:24 p.m. the task force was adjourned to reconvene at 9:30 a.m., Thursday, July 11, 1985.]

SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

THURSDAY, JULY 11, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 9:34 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. This morning we have a very impressive panel of witnesses to continue our hearings on scientists and engineers: supply and demand. Our distinguished panel today represents employers of scientists and engineers, so we are therefore looking mainly at the demand side of the market. Of course we are aware that supply and demand are linked through employment of faculty members to contribute to the production of new graduates. We're also aware of many industries who do some of the training and thus help supply their own needs.

This leads to one final point that the supply of scientists and engineers is much more than just the new graduates, although we tend to focus on them. The supply consists mainly of the large body of already trained and employed people. Many fields, particularly those that are developing most rapidly, there is a potential problem of technological obsolescence in this existing work force. And I believe that if we allow technological obsolescence to occur then we are wasting human resources very badly. I believe that we must try to find ways to keep our existing work force totally up to date and I hope our witnesses will help us discuss how to do this.

Because we have a panel of six witnesses today I would like to ask each of the witnesses to be very brief in order that we have time for questions. Your prepared statement will be printed in full in the record and we have found that question and answer, give and take has been very, very beneficial to us.

Our witnesses in order today are Jerrier Haddad, chairman of the Committee on Education and Utilization of the Engineer of the National Research Council; Daniel Zaffarano, Vice-President of Research, Iowa State University; Frank Jamerson, Director of the Physics Department, General Motors Research Laboratory; Wilbur Meier, Dean of the School of Engineering, Penn State. Robert Nysmith, the NASA Associate Administrator for Management; and Ralph Hirschman, senior vice-president for chemistry for Merck, Sharp and Dohme.

Gentlemen, we welcome you and look forward to your testimony. We will begin with you, Mr. Haddad.

STATEMENT OF JERRIER A. HADDAD, CHAIRMAN, NATIONAL RESEARCH COUNCIL COMMITTEE ON THE EDUCATION AND UTILIZATION OF THE ENGINEER, BRIARCLIFF MANOR, NY

Mr. HADDAD. Thank you very much. As you have said I am chairman of the National Research Council Committee on the Education and Utilization of the Engineer, and prior to that I had been with IBM for 39 years, having retired in 1981 as vice-president of technical personnel development.

The report of the Committee on Education and Utilization of the Engineer has been published and a copy has been provided to each member of the Task Force on Science Policy. The report presents a comprehensive study of the engineering community and that community includes not only engineers, but all those who serve in engineering capacities or in the direct support of engineering projects and that includes people educated as physicists, chemists, mathematicians, computer scientists as well as technicians and technologists. And the report was intended to assist policy makers in government, industry and academia by treating the various elements of engineering as a cohesive whole, rather than exclusively treating a single element, such as education, important though that is. In the near future, the National Research Council will publish the other reports of the committee's nine panels, each of which studied a particular element crucial to the understanding of the community as a whole.

In the Agenda it is stated that the appropriate scope for the science policy study should be limited to the issues of science policy in the narrow sense of Government policies for the support of basic and applied research. But, this study is also to include science and engineering education and manpower issues as related to graduate and postdoctoral education. Now, it is true and well-accepted that basic research and much applied research is appropriately supported by the Federal Government. The fruits of this research, to the well-being of the Nation are twofold.

First, the knowledge gained by the research is critical to the ability of the Nation to be capable of international industrial and commercial leadership, and in this regard it is academia rather than industry that has assumed the greatest responsibility for this basic research. The motivation for academia to do this has been great and manyfold. The greatest motivation is that it is now taken as an article of faith that research assures vitality and competence and thereby improves the pedagogical ability of the faculty. There is today a great deal of evidence that supports the notion that an academic that does good research makes a superior teacher. And in this day of stringent tenure requirements and student evaluations of teaching ability more often than not the same faculty members are pointed to both for good teaching and good research.

Other motivations for academia to be heavily involved in sponsored research include the supporting infrastructure that comes with research. Such things as highly effective libraries, sophisticated computing facilities, sophisticated machine shops and instrument laboratories as well as state-of-the-art research instrumentation. These things either attract or follow substantial research grants and this supporting infrastructure, while it is primarily useful to the research faculty and graduate students, heavily benefits the undergraduate quality in a number of ways. First of all, it's just there. It's available to be seen, if not used by the undergraduates and their teaching faculty and second, by its presence it attracts other world-class faculty to that campus that adds attractiveness to the institution and also attracts faculty members and outstanding students who in turn add to the attractiveness.

So far so good. But not all colleges and universities have seen fit or have been able to become research institutions. Depending on how you define it, there are less than 50 schools that fit the definition of research institutions yet, there are between 200 and 250 engineering schools that are not research institutions and yet supply the Nation with half of its entry level or bachelor of science engineers. Further, a recent study has indicated that nonresearch-type liberal arts colleges provide the Nation with a greater than suspected share of the Nation's scientists.

Therefore, we are faced with a quandary. A substantial number of the Nation's engineers and scientists are educated in nonresearch institutions. Yet research grants tend to improve the capability of academic institutions, and improve their attractiveness so that they attract more than their share of world-class faculty and outstanding undergraduate, graduate and postdoctoral students. This vexing situation is worthy of attention at the highest levels of policy making.

The conclusion that you have to reach is that research grants not only return to the Nation useful knowledge that can be exploited in world competition, but also create an environment at the college or university that makes it a better educational facility, that is, research improves pedagogical ability. The improvement of pedagogy in the education of a substantial fraction of the Nation's engineers and scientists is no less valuable to the Nation than the direct technical knowledge benefits of research—and that ought to be a high consideration in the determination of science policy. I conclude and recommend that a high priority should be given to programs that will spread the benefits of federally-sponsored research to the nonresearch institutions of the Nation.

On the issue of manpower, it ought to be noted that postdoctoral programs are heavily participated in by scientists and very little by doctoral engineers. The main problem besetting the Nation regarding doctoral engineers is the insufficient number of domestic students electing to choose faculty careers. Faculty careers just don't have the same attractiveness as do careers in industry, and this is especially true of the nonresearch colleges.

The Committee on the Education and Utilization of the Engineer developed a comprehensive flow model of that complex engineering community. Properly populated with consistent data, this model should prove useful in analyzing the engineering community and its essential elements. I believe that the development of this flow model and the accompanying definitions is a major contribution. Unfortunately, existing data bases and their varying definitions and their varying survey methodologies are inconsistent with each other. And this has made it impossible to use the flow model to its fullest advantage. We strongly recommend that a major effort be undertaken to see how best to arrive at the commonality of definitions, survey methodology, and diagramming methodology between the various governmental and private agencies that collect, analyze and disseminate data on science and engineers.

Congressman Fuqua, I've tried in this statement to focus on only two little known aspects of a very complex subject of science policy and science and engineering education. I believe that the Congress needs to become involved in assuring good science and engineering education in the nonresearch colleges and universities and also needs to be aware of the lack of compatibility among data bases on scientists and engineers because of the diversity of purposes for which they are compiled.

[The prepared statement of Mr. Haddad follows:]

Testimony of

JERRIER A. HADDAD

COMMITTEE ON SCIENCE AND TECHNOLOGY
Task Force on Government Science Policy
SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

July 11, 1985

INTRODUCTION

My name is Jerrier A. Haddad. I am chairman of the National Research Council Committee on the Education and Utilization of the Engineer. Prior to my retirement in 1981, I had been IBM vice president of technical personnel development for four years. Until 1977, over the course of a thirty-nine year career, I had served IBM in a number of technical posts including IBM vice president for Engineering, Programming and Technology. I am an electrical engineer by education, having earned a BEE from Cornell University in 1945.

Since 1968, I have been a trustee of Clarkson University and a member and chairman of the Cornell College of Engineering Advisory Council.

The report of the Committee on the Education and Utilization of the Engineer has been published and a copy has been provided to each member of the Task Force on Science Policy. The report presents a comprehensive study of the engineering community, which includes not only engineers, but all those who serve in engineering capacities or in the direct support of engineering projects. This includes people educated as physicists, chemists, mathematicians, computer scientists, as well as, technicians and technologists. The report was intended to assist policy makers in government, industry, and academe by treating the various elements of engineering as a cohesive whole, rather than exclusively treating a single element, such as education, important though it is.

In the very near future, the NRC will publish the nine reports to the Committee of the nine panels, each of which studied a particular element crucial to the understanding of the community as a whole.

STATEMENT

In the Agenda for the Study of Government Science Policy, it is stated that the appropriate scope for the Science Policy Study should be limited to the issues of science policy in the narrow sense of government policies for the support of basic and applied research. However, this study is also to include science and engineering education and manpower issues as related to graduate and post doctoral education.

It is true and well-accepted that basic research and much applied research is appropriately supported by the federal government. The fruits of this research to the well-being of the nation are twofold. First, the knowledge gained by the research is critical to the ability of the nation to be capable of international industrial and commercial leadership. In this regard, it is academe rather than industry which has assumed the greatest responsibility for basic research.

The motivation for academe to do this has been great and manifold. The greatest motivation is that it is now taken as an article of faith that research assures vitality and competence and thereby improves the pedagogical ability of faculty. There is, today, a great deal of evidence that supports the notion that an academic who does good research makes a superior teacher. In this day of stringent tenure requirements and of student evaluation of teaching ability, more often than not the same faculty members are pointed to for both good teaching and good research.

Other motivations for academe to be heavily involved in federally sponsored research include the supporting infrastructure that comes with research. Such things as highly effective libraries, sophisticated computing facilities, sophisticated machine shops and instrument laboratories, as well as state-of-the-art research instrumentation, either attract or follow substantial research grants. This supporting infrastructure, while primarily useful to the research faculty and graduate students, heavily benefits undergraduate quality in a number of ways.

First, it is there - available to be seen, if not used, by the undergraduates and their teaching faculty. Second, by its presence, it attracts other world class faculty to that campus. This adds attractiveness to that particular institution and that attractiveness attracts faculty members and outstanding students who add to the attractiveness.

So far so good. However, not all colleges and universities have seen fit or been able to become research institutions. Depending upon how one defines it, there are less than fifty schools that fit the definition of research institution. Yet there are between two hundred and two hundred fifty engineering schools that are not research institutions and yet supply the nation with half of its entry level (BS) engineers. Further, a recent study has indicated that non-research type liberal arts colleges provide the nation with a greater than suspected share of the nation's scientists.

Thus, we are faced with a quandary. A substantial number of the nation's engineers and scientists are educated in "non-research" institutions. Yet, research grants tend to improve the capability of academic institutions, and improve their attractiveness so that they attract more than their share of world class faculty and outstanding undergraduate, graduate, and post-doctoral students. This vexing situation is worthy of attention at the highest levels of policy making.

The conclusion one must reach is that research grants not only return to the nation useful knowledge that can be exploited in world competition, but also create an environment at the college or university that makes it a better educational facility; i.e., research improves pedagogical ability. The improvement of pedagogy in the education of a substantial fraction of the nation's engineers and scientists is no less valuable to the nation than the direct technical knowledge benefits of research. This should be a high consideration in the determination of science policy. I conclude and recommend that a high priority should be given to programs that will spread the benefits of federally sponsored research to the non-research institutions of the nation.

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On the issue of manpower, it should be noted that post-doctoral programs are heavily participated in by scientists and very little by doctoral engineers. The main problem besetting the nation regarding doctoral engineers is the insufficient number of domestic students electing to choose faculty careers. Faculty careers don't have the same attractiveness as do careers in industry. This is especially true of the non-research colleges of engineering.

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The Committee on the Education and Utilization of the Engineer developed a comprehensive flow model of the engineering community. Properly populated with consistent data, this model should prove very useful in analyzing the engineering community and its essential elements. I believe that the development of this flow model and the accompanying definitions is a major contribution. Unfortunately, existing data bases and their varying definitions and survey methodologies are inconsistent with each other. This has made it impossible to use the flow model to its fullest advantage. We have strongly recommended that a major effort be undertaken to see how best to arrive at commonality of definitions, survey methodology, and diagramming methodology, between the various governmental and private agencies that collect, analyze, and disseminate data on scientists and engineers.

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Congressman Fuqua, I have tried in this statement to focus on only two little known aspects of the very complex subject of science policy and science and engineering education. I believe that the Congress needs to become involved in assuring good science and engineering education in the non-research colleges and universities, and also needs to be aware of the lack of compatibility among data bases on scientists and engineers because of the diversity of purposes for which they are compiled.

Mr. **Fuqua**. Thank you very much.

Our next presenter will be Dr. Zaffarano.

[A biographical sketch of Dr. Zaffarano follows:]

Dr. Daniel Joseph Zaffarano

Daniel J. Zaffarano has served as Vice President for Research and Dean of the Graduate College at Iowa State University since March 15, 1971.

Born December 16, 1917 in Cleveland, Ohio, Dr. Zaffarano recieved his B.S. degree from Case Institute of Technology in 1939. His M.S. and Ph.D. degrees were awarded by Indiana University in 1948 and 1949.

Before joining the Iowa State staff, he was a research physicist with the National Carbon Company from 1939 to 1945, a contract administrator for the Johns Hopkins Applied Physics Laboratory from 1945 to 1946, and a graduate fellow at Indiana University from 1946 to 1949.

Dr. Zaffarano came to Iowa State as Associate Professor in 1949, was appointed Professor in 1957, and Chairman of the Department of Physics in 1961. He was reappointed Chairman in 1965 and 1970, and was awarded the title of Distinguished Professor in the College of Sciences and Humanities in 1967. He served as Physics Division Chief of the Ames Laboratory of the Atomic Energy Commission during the period 1961-1971.

The author of 25 papers in scientific journals, two patents, plus many articles, he is a Fellow of the American Society and a member of Sigma Xi and Phi Kappa Phi honoraries. Courses he has taught include elementary general physics, reactor theory, nuclear physics, musical acoustics, and electricity and magnetism. He has directed the theses of ten M.S. and 14 Ph.D. students.

Dr. Zaffarano was scientific liaison officer for the Office of Naval Research, attached to the American Embassy in London, in 1957 and 1958. He has been a consultant in several programs in the National Science Foundation, the National Academy of Sciences, the U.S. Office of Education, the American Institute of Physics, and has been a Consultant-Examiner for the North Central Association of Colleges and Universities since 1969. He was a member of the Policy Research and Analysis Advisory Committee of the National Science Foundation (1979-83).

He has served as a member of the Board of Trustees of the Argonne Universities Association (1969-75), the Universities Research Association for the Fermilab (1973-76), the Iowa Power and Light Company (1973-), and the Executive Committee of the Council on Research Policy and Graduate Education of the Land Grant Association (NASULGC) (1978-82). He served as Division Chief of the Iowa Coal Research Project in the ISU Energy and Mineral Resources Research Institute (1974-77). He was the Iowa representative on the Board of Directors of the Mid-American Solar Energy Complex (1978-82). He has been appointed by the Governor to a committee whose goal is to attract high technology industry to Iowa.

In 1975-76 he was Chairman of the Graduate Deans group in the Mid-America State Universities Association and Chairman of the Midwestern Association of Graduate Schools. He has been a member of the Board of Directors of the Council of Graduate Schools in the United States since 1975, and served as national Chairman in 1979-80.

STATEMENT OF DR. DANIEL J. ZAFFARANO, VICE PRESIDENT FOR RESEARCH, AND DEAN OF THE GRADUATE COLLEGE, IOWA STATE UNIVERSITY, AMES, IA

Dr. **Zaffarano**. Congressman Fuqua and members of the committee, I come from a State in the midst of an economic depression. And as we look around the States adjacent to us and the East Coast and West Coast that are coming out of the recession we feel like we're sisters at this present time.

I come from the West, Iowa State University. I need to establish some credentials, I guess. We are a land-grant university, we are the birthplace of the electronic digital computer, people who produced 2 million pounds of pure uranium metal during World War II, and we're the home of a multiprogram national laboratory of the Department of Energy, repository of some of the purest metals and alloys in the world.

I would like to—well, the reason I am here, I think, is that I have served as chairman of the Council of Graduate Schools in America, and I've been 35 years in the business of training people in research at the graduate level. I would like to make two points with you. I would like to address the quantity and quality of the trained manpower in this country and I would like to talk about graduate student education and faculty from the viewpoint of the university.

Back in the period of 1958 to 1970, our universities in this country had what we called traineeships. We had the NASA, NDEA, NSF, and so forth, traineeships, which were assigned on a competitive basis to each university in order to encourage the best and the brightest to go to graduate school. At the present time, at my university, we have facilities, we have faculty, 70 percent of which come to us from outside our State, trained nationally. We've got the best faculty we can find from all over the world and the United States. We have facilities to train more graduate students at the forefronts of technology. What we don't have is the money to bring these people to graduate school. You've heard the competition with industry that we have. A reasonable figure is that an undergraduate can go out and earn $28,000 at least, I guess, at the present time in engineering if he or she works in industry. We think it is reasonable for half-time study, half-time work that we offer stipends of $14,000 a year. This is above what we can now afford, but we do know that there are students out there who would come to graduate school, would study at the forefront of technology, if we could afford to offer them a traineeship with a stipend of that magnitude.

Congress canvassed our faculty and canvassed our students and I am quite sure that what I'm saying from my university is true and I think it is true from many other universities, that we have a capacity to train more students at the graduate level at the forefront of knowledge.

We have extensive programs in the microelectronics, and biotechnology, and all the areas that you can cite today that are important to the economic development of this country, and I would like the opportunity to bring more students in, even if it means displacing some foreign students. At the present time in our engineering curriculum, anywhere from 50 to 80 percent of the graduate students are students sent here from China, Taiwan, other countries. Their government pays their way, but we cannot afford to offer stipends to all the students who would like to come to our school to study these same subjects, computer science, computer engineering, and so forth.

I made an estimate. I suppose numbers like this don't make much sense, because we're trying to cut down the spending in our country, but for 5,000 students in this country, 5,000 traineeships—I said there were something like 60,000 in the period 1958 to 1970—to just offer 5,000 at the present time I estimate, including all the benefits and so forth, educational allowance or roughly $20,000 per student, that's $100 million. I would like to see our Government spend that kind of money to offer advanced education to those students who want it.

The second point I would like to make has to do with hiring with retention of faculty. As I mentioned, 70 percent of our faculty come from Harvard to Berkeley. We have excellent faculty members. And I think in the whole national scheme you will find that our university, as well as all of the midwest universities consider themselves national universities in terms of our clientele and in terms of our faculty and in terms of our importance.

After World War II is the time that I began my academic career and a lot of us did. There are going to be many retirements during this decade. Many of us are in our 60's and it's time for us to retire. We have a problem in our State because our budgeting is incremental. We have no great amounts of money for new programs. In order for us to hire a new, young, faculty member, we have to wait for an older one to retire and open up a budget position. If it is desirable, and I believe it is, to make an incremental forward step in the efforts of this country to push science and engineering ahead and bring in more ideas for innovative, economic development, if it is essential to bring more faculty members on to do that, to do more research, I think one way the Federal Government could help us would be to enable us to provide slots for new, young faculty who are being trained in these areas, but we have no positions for them, as many other universities have not.

Now, what I would like to suggest is at the present time we have the President's Young Investigators Awards, which is very good. I'm very much in favor of it. There are 100 such awards, I believe. These do not pay salary. These pay other than salary. What we need is salary money to bring new, young faculty onboard and our university could agree to commit a 10-year slot for each of these people at the time that one of our older people retires in the next 3 to 5 years. I made an estimate if we would like to bring in 100 new assistant professors in the United States, I would estimate that $50,000 each for a young faculty member, and fringe benefits, and so forth would come to about $5 million a year in order to make an impact. We have about 200 universities, I believe, that have—that could accommodate new, young faculty, that would love to accommodate new, young faculty, but can't afford it.

So, I would like to suggest that we need eight times $5 million, or about $40 million a year would do the job of providing for all of our universities in this country a step function increase in ability to train students and yet at the same time could bring in new graduate assistants and traineeships. I think we could make a step forward in the training and production of young, bright people for this country's economic development.

That's all I've got to say. Thank you.

[The prepared statement of Dr. Zaffarano follows:]

COMMITTEE ON SCIENCE & TECHNOLOGY

Task Force on Government Science Policy

Scientists and Engineers: Supply and Demand

July 11, 1985 Hearing

Members of the Task Force,

I am pleased to be invited to speak to you on the basis of my experience as Graduate Dean and Vice President for Research at Iowa State University. Not only do we have academic programs which include "agriculture and the mechanic arts", as directed by the Morrill Act, but we are the birthplace of the electronic digital computer, the producers of two million pounds of pure uranium metal during WW II, and the home of a multiprogram national laboratory of the Department of Energy.

About 30% of our faculty received their last graduate degree at Iowa State. The other 70% were recruited as the best researchers and best teachers that we could find from the major universities in the United States and abroad. In almost every department one can find young faculty members who have recently arrived with research degrees from top universities from the east coast to the west coast. Similarly, more than half of our graduate students come to us from other states and foreign countries. We have a high percentage of undergraduate merit scholars, and our entering class has an average SAT score which ranks us with a half dozen top public universities in the country. We are proud of our alumni who are the CEO's of some major corporations and presidents of universities.

If our undergraduate students are so bright, and our faculty are so well trained in the best research universities, why is it that our research expenditures each year show us to be only average among the top 100 research universities?

A. Attracting Top Graduate Students

One of the reasons has to do with our limited ability to compete with other universities in the recruitment of the very best potential graduate students in the country. Bright, hard-working, creative graduate students both inspire and help to carry out the ideas of faculty members whose daily assignments of teaching, student advising, committee work and service limit the time they have available for the pursuit of new knowledge.

To some prospective graduate students, studying the high tech sciences and engineering in a state where there are more hogs than people seems difficult to rationalize, but they would come anyway if we could award fellowships and traineeships to support their stipends. We have excellent faculty members and facilities available to bring more young people to the forefronts of science and engineering--students who could eventually contribute to economic development--if we could admit these students with stipend support if they cannot afford to forego the economic reward associated with a job immediately after achieving the bachelor's degree. The NDEA, NIH, NSF, and NASA traineeship programs which supported 60,000 graduate students through formula allocations in 1958 to 1970 to universities with capacity for additional graduate student training should be reconsidered and should serve as models for new programs to augment our greatest natural resource--well disciplined and creative young minds. Foreign governments provide subsidies for some of their best young people to travel to the United States to obtain an advanced degree. It is unfortunate that our own country cannot provide living expenses for most of our best and brightest who would like to study toward an advanced degree, but cannot afford the cost.

B. Hiring and Retention of Faculty

We are not able to add faculty members with training and experience in rapidly developing fields such as computer science, analytical instrumentation and biotechnology as rapidly as we should to serve national needs. Our enrollment is no longer in a period of rapid growth, and our state legislature cannot be expected to provide more than incremental funding.

During the present decade many of the faculty members who began their academic careers in the post-war era will reach retirement age. Great help could be provided by the federal government to universities like mine which are unable to hire replacement faculty until a retiree vacates a budget position. A federal support program could be designed to provide salary for a limited term (perhaps three years) to permit us to appoint young faculty members in fields of rapid technological development to tenure-track positions. Universities could agree to earmark the budget lines of retirees in the next three years for these candidates. In this way, attractive university positions in important high-tech areas would be created now and would be filled without waiting for anticipated retirements.

The competition for new faculty members in high tech S/E fields requires us to construct inducements which include salaries of $34,000 or more for new assistant professors, commitments for equipment purchases in the $50,000-$100,000 range, space renovation agreements, summer employment, technician and graduate student support. Prospective faculty members are concerned about computing costs and travel funds to professional meetings.

A relatively new phenomenon in faculty hiring is the "tie-in" package in which a potential faculty member will agree to come if a position for the spouse is also provided. Jobs for two people at once are easier to accommodate in urban universities where nearby academic institutions or industries can provide alternative employment.

The small pool of women and minorities available in S/E fields is of continuing concern as we follow affirmative action procedures. Some increase in the number of potential women faculty members in engineering, computer science, and business is evident, but black and other minority Ph.D. graduates remain in short supply.

NEED FOR BASICS IN GRADUATE EDUCATION

In the 1960's various national committees called for new directions in graduate education. Program reviews were imposed both internally and externally. The report of a committee chaired by Frank Newman in 1973 announced that "Graduate education in the U.S. is in trouble". Many universities were quick to respond, and interdisciplinary reorganizations of traditional disciplines appeared. Environmental science, information science, energy engineering, communications, and industrial technology became a few of the new areas of graduate study. Now we also have biotechnology, toxicology, computer science, immunology, and computer engineering, among others. Is the student who receives his graduate degree under the aegis of industrial technology better equipped to understand the rapidly changing world of science and engineering than one who is trained in the comparatively narrow field of mechanical engineering? I don't think so. I believe students are best served for the future of science and engineering by in-depth study in the traditional disciplines, with careful guidance and training in the methodology of research. The comparatively new fields of artificial intelligence, nondestructive evaluation, biomedical engineering, and microelectronics, for example, contain many subsets of problems which can be understood and solved by people trained in the traditional disciplines, working in teams.

SPECULATIONS ON INDUSTRY-UNIVERSITY RELATIONSHIPS OF THE FUTURE

It was noted by Dr. Frank Sprow of Exxon in one of these hearings on May 22 that universities can provide good low cost technical help (graduate students) and poor equipment, whereas industry has high cost technical help and good equipment. In China, mutual support is achieved by having high tech factories directly on university campuses. Both students and faculty members have access to the factory equipment. Plant managers have access to faculty expertise and student help.

High tech industries see the need for keeping abreast of basic research, but understandably spend most of their research allocations on applied problems with short-time payoff. In biotechnology, for example, it now appears that most companies will not see large profits soon from their investments in basic research, and they will have more to gain by openly sharing their knowledge and results with their counterparts in universities. In a manner analogous to the long established relationship between USDA supported collaborators who often have faculty rank on university campuses, we now have some industry-supported collaborators working in university laboratories, participating in graduate student training and performing basic research in university research teams. When products emerge from research which may be of proprietary interest, the development of these is carried out off campus. The industrial collaborators have the added opportunity to meet and work with graduate students who may be prospective employees. Many universities encourage consultant relationships between their faculty members and industry and offer free access to library and computer facilities for limited industrial work.

The willingness of industry and universities to work together today could hardly have been predicted one or two decades ago. Most universities are willing to proceed cautiously to solve problems of handling proprietary information vis-a-vis the traditional openness of graduate education and research. Unless an unexpected economic crisis interferes, I would encourage greater federal involvement in at least two ways:

1. Providing increased special support for research projects proposed jointly by industrial and university sponsors.
2. Reestablishing formula grants to qualified universities for stipends which will support top students for graduate study in fields which can contribute to economic development of the country. We need all the "trained intelligence" (described by A. N. Whitehead) we can produce.

D. J. Zaffarano
July 11, 1985

Mr. **FUQUA**. Thank you very much, Dr. Zaffarano.

Dr. Jamerson.

[A biographical sketch of Dr. Jamerson follows:]

DR. FRANK E. JAMERSON

Jamerson, Frank E(dward). Born Lowell, MA, Nov. 5, 1927; married 1950, 5 children. B.S. Physics, Massachusetts Institute of Technology, 1948; fellow, University of Notre Dame, 1949–51; Ph.D., Physics, University of Notre Dame, 1952.

Physicist, Atomics Branch, U.S. Naval Research Laboratory, Washington D.C., 1951–52; head, neutron physics section, Reactors Branch, 1954–57. Sr. Scientist, Atomic Power Division, Westinghouse Electric Corporation, 1953. Senior research physicist, Nuclear Power Engineering Department, Research Laboratories, General Motors Corporation, 1957–61; Physics Department, 1961–63; supervisor, physical electronics group, Physics Department, 1963–69; head, Physics Department, 1969-present. Management of research in: solid state physics, interface physics, surface physics, chemical physics, molecular physics electro optical physics, metal physics and deformation.

National Academy of Sciences National Bureau of Standards Evaluation Panel, Office of Air and Water Measurement, Member, 1971–72; Chairman, 1973–77. Member, NAS-NBS Evaluation Panel, Institute for Materials Research, 1974–77; Member-at-Large, 1977–78. Member, NRC-NBS Evaluation Panel for the National Measurement Laboratory, 1978–80. American Institute of Physics. Advisory Committee on Corporate Associates, Chairman, 1976–79, Member, 1979–1981; Corporate Associate for General Motors, 1970-present; Member, Nominating Committee, 1981–82; Chairman, Committee for Public Policy, 1985-present, Member, 1982–85; AIP representative to the American Association for the Advancement of Science Section Committee P, Industrial Science, 1983–86. American Physical Society. Committee on Education, 1983–85; Chairman, Selection Committee for the 1985 Industrial Summer Intern Program. American Association of Physics Teachers. Special Committee on the Crises in Science and Mathematics Education, Member 1981-present; Member, Steering Committee for the Conference of Department Chairs. Editor, *Proceedings of the Topical Conference on Physics in the Automotive Industry*, sponsored by the American Physical Society and the American Association of Physics Teachers, 1980 (Conference Proceedings 66, American Institute of Physics).

Member, American Association for the Advancement of Science, American Association of Physics Teachers, American Physical Society, American Vacuum Society, The Institute of Electrical and Electronics Engineers, Society of Automotive Engineers, Engineering Society of Detroit, Sigma Xi. Professional honors: Certificate of Award, U.S. Naval Research Laboratory, Washington, D.C. for "Fuel Element and Core for a Neutronic Reactor," September 1966. Patent: "Wheel Speed Sensor/AM," U.S. Patent 3,593,136 (13 July 1971).

STATEMENT OF DR. FRANK E. JAMERSON, HEAD, PHYSICS DEPARTMENT, GENERAL MOTORS RESEARCH LABORATORIES, WARREN, MI

Dr. **JAMERSON**. Congressman Fuqua, I am head of the physics department of the General Motors Research Laboratories—the research lab of the new high-technology General Motors Corp. My responsibilities include the management of scientists, principally physicists, who conduct research in new materials and work on the development of new measurement methods using lasers.

I appreciate the opportunity to testify before the task force. My focus will be to share a few observations regarding scientific research from the prospective of 27 years of experience at GMR.

My primary observation is that innovation from fundamental research that ultimately leads to development of new products or processes for industry results from three principal ingredients. One, commitment; two, commitment; and three, commitment. By these I mean a commitment on the part of industrial organizations to support long-range research, a commitment by universities to produce outstanding graduates who are motivated to seek research positions in industry, and also a commitment by the Federal Government to support a continuous level of fundamental research at academic institutions that can generate the research talent needed by industry.

If each of these institutions—industry, universities, and the Federal Government—can develop and maintain this commitment, industry in the United States will surely improve its competitiveness in the worldwide marketplace.

Commitment to long-range research results in new, revolutionary ideas that can impact dramatically on our everyday lives. The transistor and the laser are examples that have changed the course of the field of communications and have brought about a new information industry.

Research commitment is producing change at General Motors. Let me offer a specific example from my experience. The physics department at the General Motors Research Laboratories has conducted research in magnetic alloys for nearly 30 years. Permanent magnets in the automobile are principally used in small electric motors, such as heater air blower motors. Recognizing that these materials are important to electric motors, the General Motors Research Laboratories made a commitment many years ago to establish a group that would conduct frontier research in this field. The initial focus was on a material called ferrite, an oxide of iron, that converted electric motors from an all-copper, wire-wound configuration to the present permanent magnet type.

Through the years, our researchers undertook studies of new materials. Research in the early 1970's focused on a new alloy called samarium-cobalt, which has magnetic properties superior to ferrite. Motor designs that would take advantage of the new higher strength magnet were readied. However, in the mid-seventies, a war in Zaire, the principal source of cobalt, sent the price of cobalt sky high. Thus it became uneconomical to use these cobalt-based magnets for automotive accessory motors.

At that point we had to change directions. We elected to embark upon more fundamental research by challenging our scientists to explore new materials and new processes that might possibly eliminate the need for cobalt. We chose the latter course since we had a long-term commitment to continued progress in magnetic materials research. Outstanding research scientists accepted the challenge and proceeded through both experimental and theoretical studies to make a sigirifcant discovery. They found a new alloy that does not use cobalt at all and in fact is iron based.

We call the material MAGNEQUENCH and it consists of neodymium, a so-called rare Earth metal, iron and boron. Our scientists utilized a special process, called melt-spinning, and this process is currently moving into production at the Delco Remy Division of General Motors. This discovery has also caused considerable excitement in the scientific community. Commitment was the key to the success of MAGNEQUENCH. Commitment by management, as well as by outstanding research scientists.

I'm going to offer you, Mr. Chairman, examples of our magnet. I'm going to move these forward. We have two types, a magnet that is being utilized in our electric motors and another version

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that we're also in production on. These are sample quantities that we would be happy for you to use as exhibits in your offices.

There is need to have continuous commitment by the Federal Government for support of academic research and academic fellowships. As illustrated by the MAGNEQUENCH example, long-term commitments, decades sometimes, are essential for the unfolding of unique discoveries. A continuous reservoir of talent is essential for long-range research programs. New people bring new ideas. From our perspective, fundamental research on materials and new physical concepts to describe the fundamental characteristics of materials will produce future benefit for industry as well as for Government programs.

Federal support of research and fellowships also implies support of facilities. We hear from our academic colleagues that much of the equipment used for small science, such as electron microscopes and lasers, is antiquated and needs replacement. Thus it is important that the Federal Government consider how best to increase the support of modern, scientific equipment at universities. Typically, research grants are not sufficient to cover capital equipment items that can cost upwards of $100,000. There is a need, particularly in the physics community, for a commitment by the Federal Government to specific funding for equipment and facilities urgently needed by these important small science research groups. Many of the students trained in these groups do enter industry.

Scientists, particularly physicists, are broadly trained in the fundamentals of their scientific discipline. Such training is still desirable since scientists do change their research interests as their careers progress. Some move into new fields; for example, a physicist in our laboratory is now involved in understanding a new chemical process that converts natural gas to a graphite fiber. Well-trained scientists are thus adaptable and accept new challenges.

Most industrial laboratories hire scientists with a Ph.D. degree to be principal investigators for independent, pioneering research. In addition, B.S. and M.S. degree graduates are hired, in some cases as science associates who work with a Ph.D. scientist. These small research teams, talent with complimentary skills, make great progress in fundamental research. In addition, the science associate can become involved in technology transfer from the research laboratory to the production unit in a company such as GM. This then allows the Ph.D. scientist to concentrate on longer range research while the science associate can bring knowledge of new technology resulting from research directly to the production unit. The technology transfer process is best facilitated if such an individual is transferred. In our MAGNEQUENCH project, we at GMR agreed to transfer to the Delco Remy Division both the inventor of the magnequench process, a Ph.D. metallurgist, by the way from Professor Zaffarano's institution, Iowa State, we're delighted for John Crow joining us from Iowa State a dozen years ago, as well as a research associate, a B.S. physicist. Thus, the movement of scientific personnel is a highly effective means of ensuring technology transfer and the utilization of that technology.

In summary, the need for new scientific talent by industry continues. As research leads to new technology and people move with that technology, new researchers and new ideas are essential for the industrial health of the Nation. Large, industrial laboratories, such as the General Motors Research Laboratories, are ready to move research knowledge into the marketplace. Although the Federal Government has an ongoing problem with its deficit, and attention to solve that problem is essential, Federal support of scientific research should receive high priority. The universities, and industry as well, will benefit from a greater and dependable commitment from the Federal Government to support graduate students and experimental facilities. Success for all will come from that commitment.

[The prepared statement of Dr. Jamerson follows:]

U.S. House of Representatives
Committee on Science & Technology
Task Force on Government Science Policy
Scientists and Engineers: Supply and Demand

Frank E. Jamerson
Head, Physics Department
General Motors Research Laboratories
Warren, Michigan 48090-9055

Thursday, 11 July 1985

My name is Frank Jamerson. I am Head of the Physics Department at the General Motors Research Laboratories, located at the GM Technical Center in Warren, Michigan. My responsibilities include the management of scientists, principally physicists who conduct research in new materials, such as solid state materials and magnetic alloys, as well as research on the development of new measurement methods using lasers.

I appreciate the opportunity to testify before the Task Force on Government Science Policy. My focus this morning will be to share with you a few observations regarding scientific research from the perspective of 27 years of experience at the General Motors Research Laboratories.

My primary observation is that innovation from fundamental research that ultimately leads to development of new products or processes for industry results from three principal ingredients -- 1) COMMITMENT, 2) COMMITMENT, and 3) COMMITMENT. By these I mean a COMMITMENT on the part of industrial organizations to support long-range research, a COMMITMENT by universities to produce outstanding graduates who are motivated to seek research positions in industry, and also a COMMITMENT by the federal government to support a continuous level of fundamental research at academic institutions that can generate the research talent needed by industry.

If each of these institutions -- industry, universities and the federal government -- can develop and maintain this COMMITMENT, industry in the United States will surely improve its competitiveness in the worldwide marketplace.

Commitment implies a steady course, a long-range view. Commitment to long-range research does result in new revolutionary ideas that can impact dramatically on our everyday lives. The transistor and the laser are examples of developments that grew from fundamental research by physicists. Both developments have changed the course of the field of communications and have brought about a new information industry.

Research commitment is producing change at General Motors. Let me offer a specific example from my experience. The Physics Department at the General Motors Research Laboratories has conducted research in magnetic alloys for nearly 30 years. Permanent magnets in the automobile are principally used in small electric motors, such as heater air blower motors. Recognizing that these materials are important to electric motors, the General Motors Research Laboratories made a commitment many years ago to establish a group that would conduct frontier research in this field. The initial focus was on a material called ferrite, an oxide of iron, that converted electric motors from an all-copper, wire-wound configuration to the present permanent magnet type.

Through the years, our researchers undertook studies of new materials. Research in the early-70's focused on a new alloy called samarium-cobalt, which has magnetic properties superior to ferrite. Motor designs that would take advantage of the new higher strength magnet were readied. However, in the mid-70's, a war in Zaire, the principal source of cobalt, sent the price of cobalt sky high. Thus it became uneconomical to use these cobalt-based magnets for automotive accessory motors.

At that point we had to change directions since application of the cobalt-based magnet was thwarted. First, we could have terminated the research project on magnets. Second, we could have turned our research back to the older material, ferrite. Third, we could embark upon more fundamental research by challenging our people to explore new materials and new processes that might possibly eliminate the need for cobalt. We chose the latter course since we had a long-term commitment to continued progress in magnetic materials research. Our outstanding research scientists accepted the challenge and proceeded through both experimental and theoretical studies to make a significant discovery. They found a new alloy that does not use cobalt at all and is, in fact, iron-based.

We call the material MAGNEQUENCH, and it consists of neodymium, a so-called rare earth metal, iron and boron. Our scientists utilized a special process, called melt-spinning, and this process is currently moving into production at the Delco Remy Division of General Motors. This discovery has also caused considerable worldwide excitement in the scientific community. Commitment was the key to the success of MAGNEQUENCH. Commitment by management, as well as by outstanding research scientists.

There is need for continuous commitment by the federal government for support of academic research and academic fellowships. As illustrated by the MAGNEQUENCH example, long-term commitments, decades sometimes, are essential for the unfolding of unique discoveries. A continuous reservoir of talent is essential for long-range research programs. New people bring new ideas. From our perspective, fundamental research on materials and new physical concepts to describe the fundamental characteristics of materials will produce future benefit for industry as well as for government programs.

Federal support of research and fellowships also implies support of facilities. We hear from our academic colleagues that much of the equipment used for "small science", such as electron microscopes, and lasers, is antiquated and needs replacement. Thus, it is important that the federal government consider how best to increase the support of modern scientific equipment at universities. Typically, research grants are not sufficient to cover capital equipment items that can cost upwards of $100,000. There is a need, particularly in the physics community, for a commitment by the federal government to specific funding for equipment and facilities urgently needed by these important "small science" research groups. Many of the students trained in these groups do enter industry.

Scientists, particularly physicists, are broadly trained in the fundamentals of their scientific discipline. Such training is still desirable since scientists do change their research interests as their careers progress. Some move into new fields: for example, a physicist who conducted fundamental experiments on the electronic structure of single crystal surfaces is now involved in understanding a chemical process that converts natural gas to a graphite fiber. Well trained scientists are thus adaptable and accept new challenges.

Most industrial laboratories hire scientists with a Ph.D. degree to be the principal investigator for independent, pioneering research. In addition, B.S. and M.S. degree graduates are hired, in some cases, as science associates who work with the Ph.D. scientist. These small research teams, talent with complementary skills, make great progress in fundamental research. In addition, the science associate can become involved in technology transfer from the research laboratory to the production unit in a company such as GM. This then allows the Ph.D. scientist to concentrate on longer-range research while the science associate can bring knowledge of new technology resulting from research directly to the production unit. The technology transfer process is best facilitated if such an individual is transferred. In our MAGNEQUENCH project, we at GMR agreed to transfer to the Delco Remy Division both the inventor of the MAGNEQUENCH process (a Ph.D. metallurgist) as well as a research associate (a B.S. physicist). Thus, the movement of scientific personnel is a highly effective means of ensuring technology transfer and the utilization of that technology.

In summary, the need for new scientific talent by industry continues. As research leads to new technology and people move with that technology, new researchers and new ideas are essential for the industrial health of the nation. Large industrial laboratories, such as the General Motors Research Laboratories, are ready to move research knowledge into the marketplace. Although the federal government has an ongoing problem with its deficit, and attention to solve that problem is essential, federal support of scientific research should receive high priority. The universities, and industry as well, will benefit from a greater and dependable commitment from the federal government to support graduate students and experimental facilities. Success for all will come from that commitment.

9 July 1985

Mr. **Fuqua**. Thank you very much.

Before we hear from the next witness, without objection permission will be granted to take photographs and other reproductive techniques that may be available retroactively.

Our next witness will be Dr. Wilbur Meier.

STATEMENT OF DR. WILBUR L. MEIER, JR., DEAN, SCHOOL OF ENGINEERING, PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PA

Dr. **Meier**. Thank you, Chairman Fuqua and members of the task force. As you have heard, I am dean of the College of Engineering at Pennsylvania State University. In addition to that, I am currently serving as president of the Institute of Industrial Engineers, and a member of the executive board of the Professional Engineers & Education Division of the National Society of Professional Engineers. And I believe I speak for all of those organizations as well as many of my fellow deans of engineering.

I speak as an employer, one who has, in our college, employed more than 50 new engineers and scientists over the past 3 years. And as—and untold hundreds of post-baccalaureate students, as graduate students, in instruction and research activities, and as well as a leading producer of engineering manpower. As a matter of fact, in the most recent year of record, 1984, we at the Pennsylvania State University produced more students at the baccalaureate level in engineering than any other school in the United States, so I believe we have a reason to comment on these issues.

I want to comment on four points. The first is the faculty shortage issue. The second is a major quality problem I believe we have in engineering education. The third has to do, and it is a pervasive one that pervades the other two, the first two, outdated and nonexistent equipment and facilities. And the final point I'd like to make is to both applaud and support previous Federal initiatives and some that are currently being proposed.

With respect to the faculty shortage issue, let me make it crystal clear to you that the faculty shortage issue is real and it is critical and it is not just a State problem. In fact it is not simply a problem of salary. There are other significant and important issues: overwhelming instructional loads; the poor state of the physical facilities and equipment and, in fact, the nonexistent facilities and equipment in selected areas; and an environment in which it is difficult to motivate faculty and excite them about their work environment and to attract people. These issues are not evenly distributed across disciplines. If you—you have heard, I'm sure that there has been a 100 percent or in excess of a 100 percent increase in the number of students studying engineering in this country over the past decade. In many of our disciplines in our university, that is a fourfold increase because some disciplines have in fact declined. And those are the critically short areas in which we are all competing, industry, universities, and Government alike for the same people. They are such areas as electrical engineering, and particularly the computer engineering part of that, aerospace engineering, aspects of mechanical engineering associated with computer-aided design and manufacturing.

We have a need to bring in equipment and facilities that were nonexistent a decade ago. Therefore, we're not only replacing outdated equipment, we are bringing in existing equipment. The key elements, then, in terms of our needs in manpower are millions of dollars for laboratory equipment, construction of new and basically nonexistent facilities, reduction of loads and maintenance, and funding for maintenance and operation of equipment.

My second point I want to talk about has to do with quality of graduates. It is often perceived that the quality of our graduates is good. And this is something we hear as well from industry. And yet I think we have a very, very serious problem with the quality of our graduates today. There is—I think the thing that is producing this indication of an improved quality or a good quality of graduates is the fact that there is an unprecedented interest in engineering today. As I indicated, there has been a fourfold increase in many of our disciplines in interest of students. We today attract the best students on our campus. The SAT scores in engineering are the best of any of the nine colleges on our campus. And, in fact, the SAT verbal scores exceed that in the College of Liberal Arts. There is, because of this unprecedented increase, we have a substantial inadequacy in opportunity for individualized instruction for students. We are, in short, massproducing our graduates. We do not have adequate opportunity for students to become involved in systems integration and design experience. We do not provide adequate hands-on opportunities, the ability to develop creativity on the part of our students, the ability to develop an appreciation for the practice of their profession, and to develop their creative skills. As a result, we are graduating people who do not have adequate laboratory preparation. And this, I would suggest to you, is like graduating surgeons who have not had adequate time in a surgical theater.

The third point, then, has to do with equipment and facilities. Our problems there are threefold. Acquisition of state-of-the-art equipment, which basically is nonexistent, and adequate numbers of stations for the massive number of students that we have. That involves creation of new laboratories and new equipment and the problem of meeting the maintenance and operating expenses to us. We are, in fact, at the wrong end of the technological telescope. If you look at the particular area of solid-state electronics, a decade and a half ago one could build a solid-state electronics laboratory for approximately $1 million. In this day and time it will take $5 to $6 million. And the reason for that is that the same technology that is driving down the price of consumer electronics is driving up the cost of laboratories, what we must provide for instruction of our students.

We did an analysis at our university, Penn State alone, in terms of the College of Engineering, of what it would cost to bring our laboratories up to the quality which we thought was adequate for undergraduate instruction and we came up with a number of $20 million—one university. We looked--if you look at research and development laboratories, we looked at what it would take in one particular laboratory, a propulsion laboratory, for additional equipment that would be required to bring us to the state of the art and be able to function adequately in research and development and we came up with a number of $2.8 million for additional equipment. Also, the issue of operation and maintenance costs is a significant one for us. We have reached the point that, in some cases, we cannot accept new equipment that is given to us because we cannot support the annual operation and maintenance costs.

Going to my fourth point, one looks at congressional action, and I want to support the past initiatives that have developed equipment grants for all sorts of scientific and engineering equipment. And I want to strongly support Chairman Fuqua's proposed University Research Facilities Revitalization Act as a very, very necessary addition.

In conclusion, I hope you understand that there is a critical Federal role to support engineering education and research. Supporting our colleges of engineering is important because we are important national resources. We are not just State resources. More than half of our graduates go to work outside the Commonwealth of Pennsylvania. Therefore, we are important national resources and should be treated as such in comparison with many other of our competitors in universities in other countries. And I will also say that another aspect of our concern is that many of our graduates' initial employment in industry comes after a baccalaureate degree as opposed to the science graduates who often have advanced degrees. Therefore, we need additional support for undergraduate equipment, not just totally graduate and research equipment, so that we can adequately prepare undergraduates for employment. If we can obtain your help, I am confident that we in the educational and research community can respond with quality graduates in the numbers needed.

[The prepared statement of Dr. Meier follows:]

Testimony of

Wilbur L. Meier, Jr.

Dean of the College of Engineering

The Pennsylvania State University

on the topic of

"Scientists and Engineers: Supply and Demand"

Before the

Committee on Science and Technology

U.S. House of Representatives

Washington, D.C.

July 11, 1985

Chairman Fuqua and Members of the Task Force:

This testimony is in response to an invitation to participate in hearings on "Scientists and Engineers: Supply and Demand." I am Wilbur L. Meier, Jr., Dean of the College of Engineering at The Pennsylvania State University. In addition, I am President of the Institute of Industrial Engineers (IIE), a non-profit, international technical and professional society of 43,000 members whose principal endeavor is productivity improvement. I also am a member of the Executive Board of the Professional Engineering in Education Practice Division of the National Society of Professional Engineers (NSPE). NSPE is a non-technical professional society representing more than 75,000 professional engineers in all disciplines nationwide. I am testifying on behalf of NSPE and IIE, as well as my fellow deans of engineering.

I am speaking as one responsible for the education of engineers who are and will be entering professional employment, and as a major employer of engineers and scientists, particularly those at the advanced degree level.

Obviously, responsibility for the supply of our nation's scientists and engineers rests with America's colleges and universities. But at a time when we need to call upon our engineering education enterprise more than ever before to respond to the needs of our increasingly high-technological economy, we are less in a position to do so than we have been in the past two decades.

Stated simply, the problems are:

1) Inadequate numbers of qualified faculty to service increasing numbers of engineering students;

2) Outdated equipment and inadequate facilities that must constantly keep pace with rapid developments in technology;

3) Insufficient government support -- both state and federal -- for engineering education and research.

There is a perception within American industry that the quality of engineering graduates today is better than it has ever been before. Such a perception leads many to believe that there really is not a crisis in engineering education in our country.

I will address this issue with two comments: in many cases, our graduates are better than they have been in the recent past. They should be. Competition for entrance into colleges of engineering is keen, and so it follows that we are admitting students of unprecedented quality. At Penn State, the SAT (Scholastic Aptitude Test) scores of engineering students are higher than those of students in any of the other nine colleges on campus. Indeed, the verbal SAT scores of engineering students are superior to those of students entering the liberal arts area.

On the other hand, the individualized instruction relating to design and creativity within these students -- the kind of individualized instruction students received decades ago when one-on-one attention was possible -- is missing. We are mass producing engineering graduates because of overwhelming numbers of students being taught by inadequate numbers of faculty in laboratories and facilities designed for less than half the students with equipment which is inadequate and outdated.

The effect of this state of affairs will not be immediately obvious in the marketplace. These graduates appear competent at first, but the innovative approach and creativity necessary to maintain America's leadership in the world marketplace will not be there. This is because it has not been possible to nurture such creativity during the student's education since there have not been sufficient numbers of faculty to provide such direction.

This brings me to my first point: shortage of engineering faculty. The shortage of engineering faculty is real. It is critical, and it is not just a problem with which the states must deal.

The issue is not just one of adequacy of salary, although salary is a factor and a matter of real concern. The crisis is due in greater part to the conditions under which engineering faculty must teach and conduct research. Severely outdated equipment and lack of facilities contribute significantly to the problem of attracting and retaining quality engineering faculty. Given current levels of financial support, engineering colleges simply cannot provide the kind of environment necessary to recruit the kind of faculty needed. This deplorable environment causes engineering students to reject consideration of careers in engineering education and research as undesirable.

Estimates of the engineering faculty shortage range from 1,567 to 6,700. (The first figure is the number of unfilled positions reported in a survey of engineering deans in 1983. The second figure is the number necessary to restore the student/faculty ratio to the levels of 1967-69 and 1975-76.)

A recent survey of engineering colleges conducted by the American Society of Engineering Education revealed that 8.5 percent of faculty positions were unfilled in the fall of 1983.

As I mentioned before, there are several factors acounting for the shortage of faculty. Included among these are overwhelming teaching loads, the deteriorating state of facilities and equipment, and the resulting poor, non-motivating environment in which students are forced to learn.

Because of increasing numbers of engineering students in recent years, faculty loads have become unmanageable. Enrollment in engineering colleges nationwide has grown by 115 percent over the last decade, while faculty numbers have increased only 14 percent. At Penn State, engineering enrollments have increased four-fold in some departments over the past 12 years.

The demand for engineers in business and industry is so strong that universities and colleges -- operating with severely restricted budgets -- cannot easily entice their graduates to go on for advanced degrees and eventually into the classroom as professors. How can academia compete with industry salaries -- for those with bachelor's degrees -- that can be anywhere from 25 percent to 300 percent more than those offered in higher education -- for engineers with Ph.D.s?

The number of engineers with bachelor's degrees who go into industry directly after graduating has doubled in the last decade. Doctoral degrees awarded in engineering dropped from 3,500 in 1970 to 2,500 in 1980, directly affecting the supply of young professors. To paraphrase others: we are eating our own seed corn.

The deterioration of lab facilities and equipment impedes faculty research and lowers faculty morale, making a move to industry more attractive for good, ambitious, young faculty. At Penn State, since 1977, of 34 faculty members who left the College of Engineering to take other professional positions, 22 went into industry.

The problem also is compounded by the fact that the shortages are not uniformly distributed throughout all discipines. Most faculty openings are in critically short areas such as computer engineering, automation and robotics, computer-aided engineering, microelectronics, and aerospace engineering.

A review of our experience at Penn State will illustrate some of these points.

In four of the areas of shortage mentioned above, we have secured endowments for professorships from priviate sources to assist us in recruiting outstanding faculty leaders. It required two years of intensive recruiting and negotiation to fill one of these. After nearly two years of intensive recruiting and unsuccessful offers, three positions remain unfilled. We lost two faculty members in microelectronics to industry. After almost two years of intensive recruiting, both of these positions, plus a newly created one, remain unfilled. Salary has not been a major issue. Availability of people and equipment and facilities are the critical issues. Salary, therefore, is just the tip of the iceberg.

During 1982-83 and 1983-84, we hired 38 new faculty in the College of Engineering. But, the net increase was two, since 36 other faculty members left the college. Because of our inability to find permanent faculty members, we have been forced to resort to temporary or fixed term appointments. Since the early 1970's. the percentage of permanent faculty hired for the College of Engineering has dropped by 21 percent, while the percentage of temporary appointments has increased 1,894 percent. The percentage of graduate assistants, with teaching responsibilities, has increased 87 percent.

We also are hiring more foreign-born faculty members. Of the 38 new appointments I mentioned earlier, nearly half of these are foreign-born.

These manpower needs will continue to increase due to the availability, or non-availability of people, as well as to fill current needs, deal with the increase in research and instructional activity, and cope with increasing numbers of retirements.

We must do something in this country to motivate and encourage new engineering graduates to go on for advanced degrees and into the pool of prospective faculty. Graduate stipends, once at the level of about half the starting salary of a bachelor's degree graduate, are now down to about one-quarter. And part and parcel of this is making starting faculty salaries more competitive with those of new engineers in business and industry.

The second serious problem facing engineering education is the deplorable condition of laboratory equipment and facilities at many of our engineering colleges.

Current estimates state that one-half of the physical plant of all universities and colleges is more than 25 years old, and one-quarter was built prior to World War II. Deans of some colleges report that their students are younger than the equipment they are using. I can report that I have faculty members who are younger than that equipment.

The problem of lab facilities is three-fold:

1) Acquisition of state-of-the-art equipment

2) Having adequate numbers of stations with this equipment to meet the needs of all students

3) Meeting the spiraling maintenance costs of the equipment.

Rapidly advancing technologies are significantly shortening the useful life span of laboratory equipment. That life span currently stands at about 10 years. But according to a 1982 report by NSPE, the average age of laboratory equipment in engineering schools nationwide is 20 to 30 years.

The National Research Council reports that the median age of instruments in engineering laboratories is about twice that of comparable industrial instrumentation. And while gifts to colleges of state-of-the-art equipment from industry are welcome, there often are not sufficient facilities to house the equipment, enough faculty to supervise their use, or enough pieces of such equipment to satisfy the needs of all students.

An additional problem in acquisition of high-tech equipment is the maintenance and operations cost. These maintenance costs often are 10 to 20 percent of the capital value of the equipment. In the Penn State College of Engineering, we have equipped our Engineering Computer Lab with $6 million of equipment over the last two years. We paid only $1.5 million of this, but are now averaging $300,000 per year in operation and maintenance costs.

The equipment and facilities problem is a critical one, since it not only affects the education of our nation's future engineers, but also seriously undermines the research enterprise in our nation's colleges and universities. As I mentioned earlier, academia is losing excellent faculty because of the often primitive conditions under which they are forced to carry out their research activities.

With reference to the third point regarding government support, I applaud Chairman Fuqua's introduction of the University Research Facilities Revitalization Act of 1985. In introducing the bill, Chairman Fuqua aptly evaluated the situation: "The condition of research facilities at colleges and universities is a critical issue affecting the future of our nation. We cannot allow the current state of decline to continue."

This legislation, aimed at rebuilding and modernizing the research facilities of our nation's colleges and universities, is long overdue. Federal support to universities, in the form of programs such as the now-defunct Graduate Research Laboratory Program snd the Institutional Grants for Science Program, which ended in the '70s, must be revitalized. Chairman Fuqua's bill is a major step in this direction.

The Department of Defense Instrumentation Program is another example of important support for our nation's academic research environment. The proposed bill to provide tax credits to industries supporting research and development at colleges and universities also is encouraging.

In short, we support any effort on the part of Congress to facilitate the "rebirth" of quality and excellence in our country's institutions of engineering education and research.

It can be argued that with current economic conditions, less revenue is available for investment in engineering education and research. But this is a fallacious argument. The alternatives are increasingly dismal, resulting in a self-defeating spiral that spins us into the ground. They set the stage for irretrievable loss of young talent and creativity, leading inevitably to the destruction of our standard of living and America's ceasing to be a leader in the world marketplace.

Now is not the time to be timid. Now is the time for bold action. The Committee on Science and Technology's establishment of this Task Force to review the mechanisms for federal support of research is an important step toward such action. I am pleased to be a part of it. I challenge this Committee and the Congress to rectify these problems. In so doing, I can assure you that the engineering educational community will succeed in producing the well-prepared, creative engineers who will enable our nation to reach its technological potential.

Mr. FUQUA. Thank you very much, Dr. Meier.

Dr. Nysmith.

STATEMENT OF DR. C. ROBERT NYSMITH, ASSOCIATE ADMINISTRATOR FOR MANAGEMENT, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC

Dr. NYSMITH. Mr. Chairman and members of the task force, as one of the major employers of scientists and engineers in the Federal Government, it is my pleasure to be here to talk about this subject because it really is of concern to us. What I'll do today is try to highlight some of the problems we're having in attracting and retaining the kind of people we need as engineers and some of the problems and concerns we have for the future, because I think it will impact the kind of education needed in the country for the future.

Historically, NASA has been able to compete quite well for scientific and engineering talent because of the nature of our work, the kind of facilities that we have, the kind of development program we have for our people, and the kind of jobs that they do every day of the week. However, we're finding it increasingly difficult to be able to compete with the—in recruiting top-quality graduates as one data point. Our acceptance rate for offers accepted has dropped from 62 percent in 1981 to 46 percent in 1984, which says we now have to work twice as hard to get the same number of people. I won't say that we're getting less quality—in fact I'll say that we're getting equally good quality—but it is just harder. The primary reason from our point of view is the salary difference. I'll point out that typically on the average we—the Government pays $3,000 to $4,000 less than industry at the B.S. level and about $4,000 to $5,000 less at the M.S. level. So, we have that industry difference. We've always been able to compete though and get good-quality people.

Our concern is heightened by the basic need of an R&D agency to remain on the cutting edge of technology—performing functions that are critical for the country to maintain leadership in aerospace. We've been able to do this only by employing top-quality people. Expanding on this point, NASA has built up over the years somewhat of a unique team relationship with the industry and university community where all work together and during the Apollo era, in fact, NASA employed about 35,000 civil servants—about half of which were scientists and engineers—and had up to 400,000 individuals in the private sector that were involved in our mission. Even today, 83 percent of our budget goes out to contractors who employ about 120,000 individuals, and we have varying arrangements with about 250 colleges and universities to participate with us in the program. However, we must maintain an in-house expertise to assure the accomplishments of our mission in the most economical and efficient manner possible.

We've reached a juncture where we must concentrate on maintaining the full range and mix of in-house skills to provide R&D leadership, and this is becoming extremely difficult in certain skill areas such as computer science. As an example, just this past year our Ames Research Center in California had an increased need for in-house capability in computer development and applications to support our Numerical Aerodynamics Simulation Project Office, which is a large, very sophisticated computer system. We had 10 senior level career computer-related and electronics engineering vacancies announced in early February. This attracted nine eligible candidates despite extraordinary recruiting efforts outside the Government. Of the nine eligibles, three received offers and two declined those offers. So, after a 4-month effort, 9 of the 10 positions still remain unfilled. Typically, in the area of computer science we're finding the difference between the salaries we offer and what industry offers is on the order of $10,000. Now at that kind of difference we're almost not even able to compete in an area. That is a real concern to us.

Examples, such as I've just mentioned, will become more and more frequent, we believe, when one considers the projected supply and demand of engineering graduates. As you are well aware, and I'm sure you have been and will be told by others, freshman enrollment in engineering schools decreased overall in 1983 and this trend is expected to increase. The National Science Foundation projects an average shortage of aeronautical engineers of about 23,500 individuals and computer specialists of about 128,000 people by 1987. Additionally, the Bureau of Labor Statistics projects substantial increased demands for engineers by 1995, including a 41-percent increase for aeronautical, a 65-percent increase for electrical, and an 85-percent increase for computer science. So therefore, we're going to have less scientists and engineers of the future, but the requirements, I believe, are going to be even higher and our ability to compete is going to get even harder.

Another specific reason for our concern is the current work force within NASA. Today, just a little bit over 11 percent of our scientists and engineers are eligible for optional retirement. That means they can walk out the door any day. And over the past 3 years, about 17 to 20 percent of those eligible employees have walked out the door. And so of 11 percent that are eligible, typically we lose about one-fifth of those every year. They do leave. And we're getting an aging work force. Even if the rate of election remains the same over the next 5 years, the actual number of retirements will increase annually because more and more employees are becoming eligible. About 17 percent of our scientists and engineers will be eligible for retirement by 1989, even after allowing for a reasonable number of retirements along the way.

Within the constraints under which we operate we have initiated a concerted effort to enrich our professional talent base with recent college graduates. During fiscal year 1982 through fiscal year 1984 we hired about 1,500 scientists and engineers, most of whom were at the college graduate level.

Additionally, each of our field installations engages in extensive college recruiting nationwide, and next to the Department of Defense, we're the Federal Government's largest employer of cooperative education students. Both our college recruiting and cooperative education programs place significant emphasis on increasing the number of women and minorities in our scientific and engineering work force, and we have made progress. The percentage of minorities has increased from just over 4 percent in 1975 to about 8½ percent in 1984, while our women scientists and engineers have increased by almost a factor of 3 from 2.9 percent to 7.4 percent during the same timeframe.

In closing let me again thank you, Mr. Chairman, for this opportunity, and reemphasize that I do not believe we can overstate the seriousness of NASA's need to be competitive in hiring the best and brightest among the scientific and engineering talent available now and in the future. However, our concern is not just that we get more of the available talent. We are also very interested in doing whatever we can to help enlarge and raise the quality and quantity of the overall national talent pool.

Thank you.

[The prepared statement of Dr. Nysmith follows:]

Statement by

C. Robert Nysmith
Associate Administrator
Office of Management

National Aeronautics and Space Administration

before the

Task Force on Science Policy
Committee on Science and Technology
House of Representatives

Mr. Chairman and Distinguished Members of the Task Force:

I am especially pleased to be here today to discuss a matter which is of critical concern to NASA now and for the future. Historically, NASA has been able to compete quite well for scientific and engineering talent because of the exciting nature of our mission, our unparalleled facilities, the educational opportunities we offer, and the challenging jobs individuals are given to perform. However, we are finding it increasingly difficult to compete with the private sector in recruiting top quality graduates in science and engineering because of our salary differences. Our acceptance rate for offers to recent engineering graduates has dropped from 62 percent in 1981 to 46 percent in 1984. Our toughest competitors are aerospace firms performing Government contracts. They can offer the higher salaries and better benefits and still provide the excitement and challenge of association and involvement with the Nation's space achievements.

Our concern, based on recent trends, is heightened by the basic need of a research and development agency to remain on the cutting edge of technology--performing functions that are critical for this country to maintain its leadership in aerospace. We have been able to do this only by employing top quality people.

Let me expand on this point. Since its inception, NASA has accomplished its mission through a unique team relationship with the private sector and educational institutions. During the Apollo Era, NASA employed approximately 35,000 civil servants and had up to 400,000 individuals in the private sector involved in our mission. Even today, 83 percent of our budget goes to contractors who employ about 120,000 individuals on NASA activities, and we have varying arrangements with some 250 colleges and universities. However, we must maintain an in-house expertise to assure the accomplishments of our mission in the most economical and efficient manner possible. It is our 21,000 civil service employees who perform this essential function.

We have reached a juncture where we must concentrate on maintaining the full-range and mix of in-house skills to provide R&D leadership in several areas of rapidly changing technology. This is extremely difficult in certain skill areas such as computer science. As an example, this past year our Ames Research Center in California had an increased need for in-house capability in computer development and applications to support its Numerical Aerodynamics Simulation (NAS) Project Office. Ten senior level computer-related and electronics engineering vacancies announced in early February attracted only nine eligible candidates despite extraordinary recruiting efforts outside the Government. Of the nine eligibles, three received offers and two of them declined due to salary. After a four-month effort, nine of the positions remain unfilled.

We believe examples such as I just mentioned will become more and more frequent when one considers the projected supply and demand of engineering graduates. As you are well aware, and I am sure have been or will be told by others, freshman enrollment in engineering schools decreased overall in 1983, and this trend is expected to continue. The National Science Foundation projects a average shortage of aeronautical engineers (23,500) and computer specialists (128,000) by 1987. Additionally, the Bureau of Labor Statistics projects substantial increased demands for engineers by 1995, including a 41 percent increase for aeronautical, a 65 percent increase for electrical and an 85 percent increase for computer specialists.

Focusing on some specific reasons for NASA's concern, I want to first mention that retirement eligibles are an increasing segment of our work force. Currently 11.2 percent of our scientists and engineers are eligible for optional retirement--meaning they could walk out the door today. Over the past three years, about 17-20 percent of all eligible employees have elected to do so annually. Even if that rate of election remains constant over the next five years, the actual number of retirements will increase annually because more and more employees will become eligible. Most significant is the fact that 17 percent of our scientists and engineers will be eligible for retirement by 1989, even after allowing for a reasonable number of retirements along the way.

Within the constraints under which we operate, NASA has initiated a concerted effort to enrich our professional talent base with recent college graduates. During FY 1982 through FY 1984, we hired about 1,500 scientists and engineers, and over seventy percent of them were at the GS-9 level and below which was a significant increase over the 50 to 55 percent hired at that level in previous years. During all of this time, we have found the quality of the graduates to be consistently high. At the same time, about two-thirds of our losses have occurred at the GS/GM 13-15 levels. Thus, we may face a serious senior leadership problem in the future if we cannot continue to attract quality replacement candidates.

To meet the challenge of maintaining a high quality scientific and engineering workforce, NASA expends a great deal of time and resources. We provide significant training and educational opportunities for our own employees. In FY 1984, for example, we provided training to almost 60 percent of our scientists and engineers at a cost of more than $3,700,000 and 363,000 hours.

Additionally, each of our field installations engages in extensive college recruiting nationwide, and next to the Department of Defense, we are the Federal Government's largest employer of co-operative education students. Both our college recruiting and co-operative education programs place significant emphasis on increasing the number of women and minorities in our scientific and engineering workforce, and we have made progress. Our percentage of minorities has increased from 4.4 percent in 1975 to 8.6 percent in FY 1984 while our women scientists and engineers have increased from 2.9 percent to 7.4 percent during the same timeframe. Through NASA educational services, student educational and research opportunities and faculty opportunities, we hope to see continued growth in our numbers of minorities and women.

In closing, let me again thank you, Mr. Chairman, for this opportunity and re-emphasis that I do not believe we can over-state the seriousness of NASA's need to be competitive in hiring the best and brightest among the scientific and engineering talent available, now and in the years to come. However, our concern is not just that we get more of the available talent. We are also very interested in doing what we can to help enlarge and raise the quality of the overall, national talent pool.

Mr. **Fuqua**. Thank you very much, Dr. Nysmith.

Now, our concluding presenter will be Dr. Hirschmann.

[A biographical sketch of Dr. Hirschmann follows:]

Name: Ralph F. Hirschmann.

Address: 740 Palmer Place, Blue Bell, Pennsylvania 19422.

Date of birth: May 6, 1922.

Place of birth: Fuerth, Bavaria, Germany.

Citizenship: U.S.A.—February 19, 1944 (San Francisco).

Marital status: Married, two children.

Education: B.A., 1943, Oberlin College, Oberlin, Ohio; M.A., 1948, University of Wisconsin, Madison, Wisconsin; Ph.D., 1950, University of Wisconsin, Madison, Wisconsin (Organic Chemistry).

Military service: United States Army, 1943-1946.

Professional career: 1950, Chemist—Developmental Research, Merck & Co., Inc., Rahway, NJ 07065; 1954, Senior Chemist—Developmental Research; 1957 Section Head—Developmental Research; 1958, Research Associate—Fundamental Research; 1964, Assistant Director—Exploratory Research; 1968, Director of Peptide Research; 1969, Director of Protein Chemistry; 1971, Senior Director—New Lead Discovery; 1972, Senior Director—Medicinal Chemistry; Merck & Co., Inc., West Point, PA 19486; 1974, Executive Director—Medicinal Chemistry; 1976, Vice President—Basic Research; Merck & Co., Inc., Rahway, NJ 07065; 1978, Senior Vice President—Basic Research; 1984-, Senior Vice President—Chemistry.

Major research interests: (1) chemistry and biology of antiinflammatory steroids; (2) carbohydrate chemistry; (3) synthetic methods in peptide chemistry; (4) chemistry, conformation, biology and structure activity relationships of hypothalamic releasing factors, especially TRH and somatostatin; (5) design, synthesis and evaluation of compounds of potential value in (a) inflammatory disease, (b) cardiovascular and renal disorders, (c) disorders relating to mental health and the nervous system, and (d) endocrine disease; (6) polyvalent drugs.

Committees and boards: 1973-1977, Editorial board: *Journal of Organic Chemistry Organic Reactions Hypertension;* 1976-84, Advisory board: *Organic Reactions;* 1978-1982, NIH Medicinal Chemistry A Study Section; Gordon Research Conferences; 1978, Cochairman—Chemistry & Biology of Peptides; 1981-, Board of Trustees; 1983-1984, Vice Chairman; 1984-, Chairman; 1980, Program Chairman—17th National Medicinal Chemistry Symposium; 1980, NRC Seminar Group: Graduate Programs and Their Graduates; 1982-1985, NRC—Committee to Survey Opportunities in the Chemical Sciences (Pimental Committee); 1983-, Advisory board: Ullmanns Enzyklopadie der Technischen Chemie; 1984-, Member: Governor's Commission on Science and Technology (New Jersey).

Awards and honors: 1969, Doctor of Science Degree (Hon.) Oberlin College; Intra-Science Research Foundation Award; 1976, Elected a Member of the American Society of Biological Chemists; 1979, Wesleyan University Distinguished Lecturer (P.A. Leermakers Symposium); 1981, Elected a Member of the American Academy of Arts and Sciences; 1983, Alan E. Pierce Award—American Peptide Symposium; 1984, Board of Directors Scientific Award—Merck & Co., Inc. (establishing endowed lectureships at Oberlin College and the University of Wisconsin); 1985, Romanes lecturer; Department of Chemistry, University of Edinburgh, Scotland; 1985, Agnes Borrowman Special Lectureship in Pharmacy—London University; 1985, Hurd Lecturer, Northwestern University; 1985, elected a Fellow of the American Association for the Advancement of Science.

Visiting professorship: University of Wisconsin.

Lectures: invited lecturer in chemistry and biochemistry at all major American universities, at several foreign universities, at Gordon Conferences, European and American Peptide Symposia, U.S. and foreign medicinal chemistry symposia, international symposia on bioorganic chemistry and on natural products chemistry.

Scientific societies: American Chemical Society, the Swiss Chemical Society, the New York Academy of Sciences; the Society of Chemical Industry, Sigma Xi, Association of Research Directors, American Diabetes Association.

STATEMENT OF DR. RALPH F. HIRSCHMANN, SENIOR VICE PRESIDENT, CHEMISTRY, MERCK, SHARP & DOHME RESEARCH LABORATORIES, RAHWAY, NJ

Dr. **Hirschmann**. Mr. Chairman and members of the task force, I appreciate to have been invited to testify before this committee concerning national needs for training in those physical and biological sciences which are crucial to our purpose, which is the improvement of our Nation's health through therapy and preventive medicine. The pharmaceutical industry not only provides for better health, but in so doing provides jobs for over 200,000 Americans and serves our economy also through exports. For example, in 1979 the pharmaceutical industry contributed well over $1 billion to our balance of trade. I should like to begin with some observations about the U.S. pharmaceutical industry, the challenge it faces from abroad, and then proceed to comment about our needs for scientists at the graduate level.

The pharmaceutical industry thrives on innovation. It is one of the most research intensive of all U.S. industries. On average, U.S. pharmaceutical companies spend 6 percent of their total sales on research and development compared to 2 percent for all industry.

Many U.S. pharmaceutical houses depend on their research laboratories to invent or develop new pharmaceuticals. Such commitment to research requires support. At Merck, our research and development budget has increased for over 25 years. In 1984, our research and development expenditures were $393 million and in 1985 we had a budget of over $430 million. But dollars alone are insufficient. The qualifications of the people whose research efforts we support are the major determinant for success.

May I briefly list for you some of the major contributions of the pharmaceutical industry to the Nation's health since 1930. I should like to say at the outset that many of the achievements resulted from fruitful interaction between basic research and academic and Government laboratories, on the one hand, and both basic, as well as more applied research in laboratories in the pharmaceutical industry. Although their respective roles in the drug-discovery process are different, there is often considerable overlap between academic/Government research and industrial research, but the interaction is required if the Nation is ultimately to benefit.

It is perhaps hard to believe that 50 years ago, hardly any of the drugs now widely prescribed by our physicians had been discovered. Consider the antibacterial agents. Prior to World War II, the sulfonamides were the only effective antibacterials available. Drugs such as streptomycin, penicillin, the cephalosporins, the aminoglycosides were not yet discovered.

The first anticancer drugs, the nitrogen mustards, were introduced into therapy in 1942. Since then, a host of diverse agents have been discovered with impressive results. For example, in 1963, advanced Hodgkin's Disease in adults was incurable, but today, combination therapy has produced a cure in about 80 percent of these patients. Complete remission can be achieved today in 97 percent of children with acute lymphocytic leukemia.

Equally impressive have been advances in the treatment of cardiovascular disease, especially hypertension. Death rates for coronary heart disease in the United States fell over 20 percent between 1968 and 1978. Improved control of high blood pressure through drugs is credited with an important role in this advance. The first thiazide diuretic was discovered about 30 years ago; the thiazides, alpha-methyldopa, and beta-adrenergic blocking agents are just some of the lifesaving drugs for the treatment of hypertension which we have learned to take for granted. Even more promising agents are becoming available or will soon be available.

Equally dramatic are advances relating to drugs affecting the central nervous system, such as drugs against Parkinson's Disease, antidepressants, antianxiety agents, and so forth. The same may be said of drugs for the treatment of chronic and degenerative inflammatory disorders, such as arthritis. While these anti-inflammatory drugs have not arrested the progress of the disease, they have enabled most of these patients to lead active and useful lives.

I could go on at length, even if I restricted myself to highlights. I have not mentioned vaccines which protect against such diseases as measles, mumps, German measles, polio, hepatitis, nor drugs useful for the treatment of ulcers, a drug for the treatment of infections caused by a herpes virus, nor antidiabetes drugs, or a large variety or hormones useful in therapy. In summary, we may properly ask, where would the practice of medicine be without contributions of the pharmaceutical industry.

Today, the pharmaceutical industry is in a stronger position to make important and innovative contributions to therapy than ever before. This is because we are gaining a better understanding of physiological processes in health and in disease at a truly remarkable rate, much of it as a consequence of basic research efforts of our colleagues in the academic world. I suspect that no time in history has been as exciting as the present in terms of our increased understanding of disease at the molecular level through chemistry and molecular biology. This information is being utilized rapidly and effectively for development of new approaches to therapy such as genetic engineering. These advances promise to bring solutions to many illnesses for which there is either no treatment available or where available therapy is not optimal. Examples include arteriosclerosis, Alzheimer's Disease, osteoporosis, heart failure, cancer, stroke, schizophrenia, arthritis, the degenerative diseases of aging, diseases of the immune system, endocrine disorders, and others.

The promises of new knowledge of living systems for drug discovery have not been lost on our competitors abroad. Indeed U.S.-based pharmaceutical houses face increasingly aggressive competition from a number of European corporations having the expertise, resources, and will to expand their share of the pharmaceutical market worldwide. In addition, we, like the United States industries, face a strong challenge from Japan. In 1964, the U.S. share of world-drug research and development was 65 percent. But, in 1978, it was only 28 percent, which is a very dramatic drop.

The preceding observations establish that a strong U.S.-based pharmaceutical industry is an important national asset, that research-based pharmaceutical houses, such as Merck, are continuing to provide unusually generous support for research and development programs, and that those corporations who are most innovative and creative are likely to continue to fare best. The availability to us for employment of well trained Ph.D.'s in the chemical and biological sciences, conversant with the most recent techniques, is essential to our survival. Moreover, we require scientists trained in such diverse disciplines as chemistry, biochemistry, pharmacology, immunology, microbiology, statistics, pharmacy, molecular biology, toxicology, endocrinology, and engineering. Clearly, we also require physicians.

I should now like to list disciplines where I perceive a significant shortage in well-trained Ph.D.'s available to us for employment. This includes, in my opinion, analytical chemists, largely because of the enormous demand for such scientists as a result of regulations that protect our health and environment, and also because the field is a dynamic one. Additional funding to induce and enable more graduate students to alter this field may provide a solution. I am talking about additional funding, including instrumentation funding, lest we rob Peter to pay Paul. The University Research Facilities Revitalization Act of 1985, which you, Mr. Chairman, have introduced, would clearly be helpful in this context, since it would support facilities and equipment and not at the expense of existing university research and development programs.

Such funding may also overcome the shortage of scientists available to us at the Ph.D. level for experts in the isolation and characterization of complex peptides, and proteins, and of other macromolecules. The need for such scientists is certain to increase in the years ahead.

Third, there has been a shortage of first-rate scientists, trained in in vivo pharmacology. Such scientists are essential to the discovery of better drugs. A possible solution might be to provide postdoctoral fellowships which would allow and motivate M.D.'s and Ph.D.'s trained in other disciplines to do post-doctoral research in pharmacology.

Finally I am concerned because there is a shortage of Ph.D.'s available to us who are qualified for animal health and agricultural research. The importance of these areas of research to our Nation, and indeed to the world, cannot be doubted. Yet, we find it difficult to identify an adequate number of Ph.D.'s who are both excellent scientists and who seek employment in our industry. There is a real difference in the number of qualified applicants available to us for human as compared to animal health research. Here again it may be desirable to motivate Ph.D.'s trained in other disciplines to do postdoctoral research relating to animal health and agriculture.

I urge, therefore, Mr. Chairman, that the committee consider ways whereby increased funding, presumably through the NIH and the NSF, can be used to attract an increasing number of talented scientists into these areas of research. In this context and indeed throughout my remarks, I mean to stress excellence. Our needs will not be served if we merely increase the number of potential applicants. Scientific excellence of our future employees in all of our disciplines remains a *conditio sine qua non.*

Finally I would like to submit for the committee's consideration a few thoughts about the interdisciplinary nature of our research and in particular the interaction of Ph.D.'s and M.D.'s. There is a growing need and opportunity in the pharmaceutical industry for men and women who are trained both in medicine and in research. There is more than one way to bring this about. The joint Ph.D./M.D. programs represent one approach which deserves support. But, I hasten to add that I would not recommend support of such a dual program if the funding is achieved by reducing support for hardcore Ph.D. programs, such as organic chemistry, biochemistry, molecular biology, and so forth.

While the military draft was in effect, a number of M.D.'s learned about basic research at the forefront of the biomedical sciences at institutions such as the NIH. While they generally did not earn a formal Ph.D. degree, they were, in fact, introduced to the rigor of research in such fields as biochemistry and molecular biology. This was an entirely satisfactory alternative to the dual M.D./Ph.D. degree program. In the era of the volunteer, military forces we should seek to provide motivation for M.D.'s who have a talent for research to receive such scientific training at institutions such as the NIH.

A third approach which may desire consideration is to provide incentive and funding which would permit, for example, a Ph.D. in chemistry or in biochemistry to take courses in medical schools. Such studies need not lead to an M.D. degree, but would teach the Ph.D. about physiology and especially about disease. This would enormously broaden the scientist and make him or her a more valuable employee.

While success of research in the pharmaceutical industry is synonymous with interdisciplinary research and while I support such interdisciplinary activities with enthusiasm, I would conclude by adding a caveat. The principal task of the universities is to train Ph.D.'s who are well educated, who think critically, who can discern whether a proposed research problem is really important, and who are experts trained in depth in some field of research. Breadth, acquired at the expense of depth, is not an acceptable alternative, in my opinion. There remains an urgent need for scientists with a firm foundation in organic chemistry who understand the scientific method. By contrast, in our time the M.D. degree is not a research degree. In our desire to provide interdisciplinary training we should not lose sight of the fact that the training for an M.D. degree serves different needs from that for the Ph.D. degree.

Finally, I should like to thank you again, Mr. Chairman, for giving me the opportunity to appear before this committee.

[The prepared statement of Dr. Hirschmann follows:]

Statement of Dr. Ralph Hirschmann
Senior Vice President, Chemistry
Merck Sharp & Dohme Research Laboratories

Before the
Committee on Science and Technology
House of Representatives

on
Manpower Needs in the Pharmaceutical Industry

July 11, 1985

Statement of Dr. Ralph Hirschmann
Senior Vice President, Chemistry
Merck Sharp & Dohme Research Laboratories

Before the
Committee on Science and Technology
House of Representatives

INTRODUCTION

Chairman Fuqua, Mr. Winn and members of the Committee, my name is Ralph Hirschmann. I am Senior Vice President for Chemistry at the Merck Sharp & Dohme Research Laboratories, a division of Merck & Co., Inc. I have been employed by Merck and Company for 35 years, about fifteen of which have been spent in a senior position in research administration. My curriculum vitae is attached.

I appreciate to have been invited to testify before this committee concerning national needs for training in those physical and biological sciences which are crucial to our purpose, which is the improvement of our nation's health through therapy and preventive medicine. The pharmaceutical industry not only provides for better health but in so doing provides jobs for 200,000 Americans and serves our economy also through exports. For example, in 1979 the pharmaceutical industry contributed well over 1 billion dollars to our balance of trade. I should like to begin with some observations about the U.S. pharmaceutical industry, the challenge it faces from abroad, and then proceed to comment about our needs for scientists at the graduate levels.

THE PHARMACEUTICAL INDUSTRY

The pharmaceutical industry thrives on innovation. It is one of the most research intensive of all U.S. industries. On average U.S. pharmaceutical companies spend six percent of their total sales on research and development, compared to two percent for all industry.

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PAST ACCOMPLISHMENTS

May I briefly list for you some of the major contributions of the pharmaceutical industry to the nation's health since the 1930's. I should like to say at the outset that many of these achievements resulted from fruitful interaction between basic research in academic and government laboratories, on the one hand, and both basic as well as more applied research in laboratories in the pharmaceutical industry. Although their respective roles in the drug discovery process are different, there is often considerable overlap between academic/government research and industrial research, but the interaction is required if the nation is ultimately to benefit. It is perhaps hard to believe that fifty years ago, hardly any of the drugs now widely prescribed by our physicians had been discovered. Consider the antibacterial agents. Prior to World War II, the sulfonamides were the only effective antibacterials available. Drugs such as streptomycin, penicillin, the cephalosporins, the aminoglycosides were yet to be discovered.

The first anticancer drugs, the nitrogen mustards, were introduced into therapy in 1942. Since then, a host of diverse agents have been discovered with impressive results. For example, in 1963 advanced Hodgkin's disease in adults was incurable, but today, combination therapy has produced a cure in about 80% of these patients. Complete remission can be achieved today in 97% of children with acute lymphocytic leukemia.

Equally impressive have been advances in the treatment of cardiovascular disease, especially hypertension. Death rates for coronary heart disease in the U.S. fell over

20% between 1968 and 1978. Improved control of high blood pressure through drugs is credited with an important role in this advance. The first thiazide diuretic was discovered about thirty years ago; the thiazides, α-methyldopa, and β-adrenergic blocking agents are just some of the life-saving drugs for the treatment of hypertension which we have learned to take for granted. Even more promising agents are becoming available or will soon be available.

Equally dramatic are advances relating to drugs affecting the central nervous system such as drugs against Parkinson's disease, antidepressants, anti-anxiety agents and so forth. The same may be said of drugs for the treatment of chronic and degenerative inflammatory disorders such as arthritis. While these anti-inflammatory drugs have not arrested the progress of the disease, they have enabled most of these patients to lead active and useful lives.

I could go on at length, even if I restricted myself to highlights. I have not mentioned vaccines which protect against diseases such as measles, mumps, German measles, polio, hepatitis, nor drugs useful for the treatment of ulcers, a drug for the treatment of infections caused by a herpes virus, nor antidiabetes drugs, or a large variety of hormones useful in therapy. In summary, we may properly ask: where would the practice of medicine be without contributions of the pharmaceutical industry?

FUTURE ADVANCES

Today the pharmaceutical industry is in a stronger stronger position to make important and innovative contributions to therapy than ever before. This is because we are gaining a better understanding of physiological processes in health and in disease at a truly remarkable rate, much of it as a consequence of basic research efforts of our colleagues in the academic world. I suspect that no time in history has been as exciting as the present in terms of our increased understanding of disease at the molecular level through chemistry and molecular biology. This information is being utilized rapidly and effectively for development of new approaches to therapy such as genetic engineering. These advances promise to bring solutions to many illnesses for which there is either no treatment available, or where the available therapy is not optimal. Examples include atherosclerosis, Alzheimer's disease, osteoporosis, heart failure, cancer, stroke, schizophrenia, arthritis, the degenerative diseases of aging, diseases of the immune system, endocrine disorders and others.

FOREIGN PHARMACEUTICAL HOUSES

The promises of new knowledge of living systems for drug discovery have not been lost on our competitors abroad. Indeed, U.S.-based pharmaceutical houses face increasingly aggressive competition from a number of European corporations having the expertise, resources, and will to expand their share of the pharmaceutical market worldwide. In addition, we, like other U.S. industries, face a strong challenge from Japan.

FUTURE NEEDS

The preceding observations establish that a strong U.S.-based pharmaceutical industry is an important national asset, that research-based pharmaceutical houses such as Merck are continuing to provide unusually generous support for research and development programs, and that those corporations who are most innovative and creative are likely to continue to fare best. The availability to us for employment of well trained Ph.D.'s in the chemical and biological sciences, conversant with the most recent techniques is essential to our survival. Moreover we require scientists trained in such diverse disciplines as chemistry, biochemistry, pharmacology, immunology, microbiology, statistics, pharmacy, molecular biology, toxicology, endocrinology and engineering. Clearly we also require physicians.

I should now like to list disciplines where I perceive a significant shortage in well trained Ph.D.'s available to us for employment.

(1) This includes, in my opinion, analytical chemists, largely because of the enormous demand for such scientists as a result of regulations that protect our health and environment, and also because the field is a dynamic one. Additional funding to induce and enable more graduate students to enter this field may provide a solution. I am talking about additional funding, including instrumentation funding, lest we rob Peter to pay Paul.

(2) Such funding may also overcome the shortage of scientists available to us at the Ph.D. level who are experts in the isolation and characterization of complex peptides and proteins and of other macromolecules. The need for such scientists is certain to increase in the years ahead.

(3) Thirdly, there has been a shortage of first-rate scientists, trained in in vivo pharmacology. Such scientists are essential to the discovery of better drugs. A possible solution might be to provide postdoctoral fellowships which would allow and motivate M.D.'s or Ph.D.'s trained in other disciplines to do postdoctoral research in pharmacology.

(4) Finally I am concerned because there is a shortage of Ph.D.'s available to us who are qualified for animal health and agricultural research. The importance of these areas of research to our nation and, indeed, to the world, cannot be doubted. Yet we find it difficult to identify an adequate number of Ph.D.'s who are both excellent scientists and who seek employment in our industry. There is a real difference in the number of qualified applicants available to us for human vs. animal health research. Here again it may be desirable to motivate Ph.D.'s trained in other disciplines to do postdoctoral research relating to animal health and agriculture.

I urge, therefore, Mr. Chairman, that the Committee consider ways whereby increased funding, presumably through the NIH and the NSF, can be used to attract an increasing number of talented scientists into these areas of research. In this context, and indeed throughout my remarks, I mean to stress excellence. Our needs will not be served if we merely increase the number of potential applicants. Scientific excellence of our future employees, in all of our disciplines, remains a conditio sine qua non.

Finally I would like to submit for the Committee's consideration a few thoughts about the interdisciplinary nature of our research and in particular the interaction of Ph.D.'s and M.D.'s. There is a growing need and opportunity in the pharmaceutical industry for men and women who are trained both in medicine and in research. There is more than one way to bring this about. The joint PhD/MD programs represent one approach which deserves support. But I hasten to add that I would not recommend support of such a dual program if the funding is achieved by reducing support for "hardcore" Ph.D. programs such as organic chemistry, biochemistry, molecular biology and so forth.

While the military draft was in effect, a number of M.D.'s learned about basic research at the forefront of the biomedical sciences at institutions such as the NIH. While they generally did not earn a formal Ph.D. degree, they were - in fact -introduced to the rigor of research in such fields as biochemistry and molecular biology. This was an entirely satisfactory alternative to the dual MD/PhD degree program. In the era of the volunteer military forces, we should seek to provide motivation for M.D.'s who have a talent for research to receive such scientific training at institutions such as the NIH.

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While success of research in the pharmaceutical industry is synonymous with interdisciplinary research and while I support such interdisciplinary activities with enthusiasm, I would conclude by adding a caveat. The principal task of the universities is to train Ph.D.'s who are well educated, who think critically, who can discern whether a proposed research problem is really important and who are experts trained in depth in some field of research. Breadth, acquired at the expense of depth, is not an acceptable alternative, in my opinion. There remains an urgent need for scientists with a firm foundation in organic chemistry who understand the scientific method. By contrast, in our time the M.D. degree is not a research degree. In our desire to provide interdisciplinary training we should not lose sight of the fact that the training for an M.D. degree serves different needs from that for the Ph.D. degree.

Finally, I should like to thank you again, Mr. Chairman, for giving me the opportunity to appear before this committee.

Mr. **Fuqua**. Thank you very much

PANEL DISCUSSION

Let me thank all of our panelists for not only keeping their remarks brief, but also for very excellent statements.

Mr. Haddad, to what extent do you think that industry is contributing to the shortage of the engineering faculty by hiring a lot of the top-quality, research faculty away from universities? And do you think that this is compounding the education problems at the university level? I think Dr. Meier pointed that out during the course of his remark.

Mr. **Haddad**. I don't believe that the problem is with industry's hiring practices. The problem is one of the lack of attractiveness of an academic career to those few domestic students, engineering students, who decide to study for the Ph.D. The problem is twofold. No. 1, not enough students are studying for the Ph.D. and those that do are those that seek to work in industry in the first place. The best indication I have is that there is no shortage of Ph.D.'s as far as industry is concerned.

Mr. **Fuqua**. Ph.D.'s from——

Mr. **Haddad**. For industry. While the Ph.D. entering into industry obviously gets more starting money than the master or the bachelor, the facts are that it takes accumulated income of 20 years to make up the difference between if an engineer went into industry at the bachelor level as compared to going in at the Ph.D. level. Even though he makes more money at the Ph.D. level, it takes 20 years to make up that difference.

So industry is not really bidding up, if you will, the Ph.D.'s, so I don't see that you can accuse industry of being overzealous in that. I think the problem is rather the lack of attractiveness of the academic level and I believe that's a very complex problem. The educational establishment has kind of kept in pace with itself, but not competitive with industry in terms of equipment, in terms of workload. You see the thing that's happened is that the workload on faculty has increased quite substantially. Someone else mentioned that the number of engineering students has doubled in a decade. By all rights the faculty should have doubled in that decade, but it certainly didn't. And there was some ability, a great deal of ability on the part of faculty to take care of that increase, but now the situation has come to the point where the workload on the professors is very great. It adds to the unattractiveness of an academic career and they are sort of in a "Catch-22." The only way they can cure the problem to make it look more attractive is to hire more faculty to begin with and they can't do that because it is unattractive.

Let me throw something else out: should the Federal Government, and we discussed this with previous meetings, should the Federal Government try to get into predicting and regulating the supply of scientists and engineers in order to target certain education programs for the future? Now, there is an inclination to try to do that, it's been pointed out, areas like in electrical engineering, or computer science, or however it is defined in the various schools.

Or should we—there's a shortage of those today. Now, if we made an effort to move into that field, would we find it 5, 10 years from now that that was the wrong move?

I remember back after the National Defense Education Act was passed and in the late 1960's we had a lot of engineers driving taxicabs and running elevators because there was no demand for their talents at that particular time, which was, I think, a classic case of the impropriety of trying to—the Government—manage the manpower needs. But, so apparently we haven't been too successful in trying to manage, if you want to refer to that as manage, the—how do we try to do that. And I'll throw that over to you.

Dr. JAMERSON. I'd like to attack that one from the following point of view. The situation is market-driven. That is, people choosing a career by selecting a certain course in a college or university, those opinions are made, depending on their perception at the time they're in college, of what the marketplace is out there for a job. And you're quite correct in the fact that the availabilty of jobs does cycle. However, it is a market-driven situation, so that there are adjustments that are made in time.

I think perhaps if we did a better job in training, in educating our people so that they would become, although targeted for a certain area, are adaptable if they find themselves in a situation where their marketplace is down. One area of perhaps importance is the area of communication skills. Many times we find people who are highly skilled in engineering and science are not very well skilled in communication. From the standpoint of selling themselves in the job market that is an essential and important key ingredient to the success or lack of success in that area. So, I think that it is difficult to regulate, it seems to me, the flow of people into the engineering, scientific marketplace. However, we should provide the opportunities and keep in mind that our needs are going to increase so there needs to be a development and a marketing of engineering and science to not only our college graduates and college undergraduates, but also the students from kindergarten through 12.

Dr. MEIER. I agree with you, Chairman Fuqua, that we shouldn't try to—or whether I'm reading something into what you said, that we shouldn't try to manage this issue, but I believe we are orders of magnitude away from adequacy of support in terms of preparation of engineers for the existing marketplace. And therefore, I don't think we're in any danger of a massive oversupply. I believe the oversupply that we spoke about was primarily Government driven. Cancellations of Government contracts in the aerospace industry, and in fact, in most cases, those engineers that were reputed to be driving taxicabs were not educated as engineers, but in fact, were people who were employed as engineers in these companies, and were then let go when the bulge went by.

So, I think that there is that aspect that we need to keep in mind. I think as well, and I want to, if I may, while I have the microphone, address the issue that my colleague, Mr. Haddad brought up on the other end and that has to do with the lack of attractiveness of academic careers today. And I think that is, as he said, a very complex and a very serious problem. That lack of attractiveness, I believe, is having its impact with out existing students, and in fact impacting rather substantially those that are going on for advanced degrees. That it's not all just the attractiveness of an industrial career, but the lack of attractiveness of an academic career.

I would disagree with him that this is something that could and should have been totally handled, could have been handled to some degree, on the campuses. I think that it is in—it is concentrated in selected areas, as I pointed out. And that these areas by all measures that I see are areas that are going to continue to remain—in which there will be very strong demands in the future, based on just industrial competitiveness of this country. And I think that the solution to it is again a very complex issue. But clearly we're not producing enough people at advanced degree levels to satisfy what is the existing market and I would point out and also note that the retirement issue in universities is a very significant one in the very near future and the demand is going to continue to be very strong just based on, if nothing else, replacement of retirements. So, we have really a very complex and very serious issue that needs to be addressed.

Mr. **Fuqua**. Let me follow that up with a question to, probably to you and to Dr. Zaffarano because you come from academic institutions.

Is it necessary, say in the field of engineering or some of the others that in the early years of training for the students that they be taught by Ph.D.'s? Can we have bachelors or masters, particularly in the early parts of their training program? The second part of that is when you say qualified faculty, there are two that I see and I try to look at it both from the administrator in the educational institution's point of view and also from the point of view from where I sit, but there are two kinds of faculty. One is research faculty, they come in and they bring money in. Then there is the teacher faculty that is a very excellent teacher, but doesn't really care that much about research. And it seems to be that there may be a role for both of those in an institution. And possibly a readjustment of your manpower needs in teaching as well as research. But many times I find faculty or particularly administrators, they look for the person who will bring in $1 million a year or more versus the one that might be a very good teacher, but doesn't involve himself in applying for grants and so forth.

Dr. **Meier**. Well, in looking at that again there is not a very simple solution to that. I think that the point was made by someone else on this committee, I believe Dan made it, that it is most often the same people who are outstanding in teaching and research. And we must be concerned and continue to be concerned about maintaining our faculty at the forefront of the cutting edge of technology because technology is changing, so there are some drivers for having research faculty that are- that do not relate to just bringing in money to the institution.

The other issue that I would point out there is that in a university, which is a major research university, as ours is, as well, one cannot afford to have large numbers of faculty that are dedicated to only one aspect of your program. You can't have people in—who are pure researchers, if you please, or just dedicated to teaching. You've got to have more universal mechanics in order just to be able to meet the varying demands and needs that you have. So, it's not—while I would agree with you you can have some very distinguished people who can help you, and we do, who are primarily oriented toward teaching and as well some who are primarily oriented toward research. The great bulk of our faculty we have to have in both catagories for the reasons I mentioned.

Dr. ZAFFARANO. A simple answer to your question of why you have to have a Ph.D. to teach freshmen and sophomores, the answer is of course, no. And we have excellent teachers who have no Ph.D.'s and we use them as much as we possibly can. They are saturated. I'm vice president for research at the university. My job is to bring in research funds and train graduate students at the highest level. My frustration at the present time is that I cannot get our faculties in computer science and business and engineering where the saturation is at the student level. I can't get them to do more research because they're too busy. They simply don't have time to do research at the present time. I am frustrated because I am trying to push university interaction with industry and I am trying to build bridges for research with our engineering faculty. Our faculty members teach 12 to 15 hours a week, which is more than twice what they used to a decade ago and if they put an hour for preparation and an hour for grading and so forth after class these people are saturated with work and they simply—they don't have time. So, I would say that our faculty, both the research faculty and the teaching faculty, those are the people who don't do research anymore, are saturated and the only way that we will get more of the forefront research being done in our college of engineering and with many of the areas of science is by hiring new young people. And I made the point that I would just love to be able to bring in young people with the promise of a 10-year contract position, but I have to wait until a spot opens up before I can bring in a new person. And I'm saying that if the Federal Government could help us out by providing salaries for incoming young faculty members and we would commit an anticipated retirement, we could get started immediately in doing more of the kind of training that I think the country needs.

Dr. JAMERSON. I'd just like to raise a point, Mr. Chairman, that flow is in two directions. That is, there are people, researchers, engineers, and scientists who leave industry for academic positions, so we do contribute in a certain way to academic positions. Another idea that might be considered is that as an engineer or scientist retires from industry that person who still has some outstanding skills to contribute in an academic institution, whether it be a college or university or other. That is another solution to alleviate some of the shortages of trained people who are skilled to take on those teaching roles.

Dr. ZAFFARANO. I should say we do that already. We have several people who have retired from industry and who are teaching in our engineering college.

Mr. FUQUA. And do you utilize those who don't necessarily have Ph.D. degrees?

Dr. ZAFFARANO. Oh, sure.

Mr. FUQUA. Because I think the experience would be very valuable.

Dr. ZAFFARANO. The Ph.D. degree is important when you're training graduate students, when you're training new Ph.D.'s, but unless you're doing that you don't have to have a Ph.D. to be a good teacher.

Mr. FUQUA. Dr. Nysmith, you mentioned the problem of salaries in NASA and this is typical of one of the problems that we have. And I'm wondering like the NASA laboratory that if they were maybe converted where they were operated similar in the fashion as the DOE laboratories to a nonprofit operator and then that relieves that problem. And I'm not speaking about the NASA headquarters and maybe the facilities at—well maybe at some of the other laboratories though that they could—well, do you think that might be a solution to that? I'm not advocating it. I'm asking your opinion.

Dr. NYSMITH. Well that's something that we are looking into too. Just exactly that question. Because we do have one laboratory, the Jet-Propulsion Laboratory that works very, very effectively. We do have—well let us call it the culture of NASA where over the past 60 years from the NACA days that people at the laboratories are proud of being part of NASA. We have other centers too who are, what I tend to think of, are in various stages of being converted to a Government-owned, contractor-operated facility as in an example, Kennedy. As you well know-most of the people at Kennedy processing the shuttle payloads and whatever are contractor people. So, we have a minority workforce there. I think it is a thought to consider. I think it would take a long time.

Mr. FUQUA. Well, you mentioned Ames and the computational simulation lab—a very highly sophisticated operation—and other things that go on at Ames come to my mind and probably at Lewis, as well as Langley that might fit under that category.

Dr. NYSMITH. It would, and one might not have to take such drastic steps. You know the Civil Service Reform Act allowed for personnel demonstration projects to be initiated that stand aside some of the salary requirements, and we have underway within the Agency a study to look at trying to do a project like that at Ames to allow a lot more flexibility. So those kinds of things, I think, are things we're looking at, but most of them are, let's say, a little longer term than what our real problem is, because our problem seems to be getting worse almost daily in the salary competitive point of view.

You mentioned Ames, and that's a unique situation because they're in the Silicon Valley and they are just not competing at all. And I mentioned the one case, but at Ames they have—you know, the cost of living, a house out there is just impossible. And we're trying to work that one, but salary limitations are a big problem. I say we are looking at that GOCO idea, and the merging over, and we plan to keep looking at it and if it makes some sense we'll get back and talk to you about how that looks.

Mr. FUQUA. We have a vote right now and we're going to have to take a short recess while we run to vote. We'll be right back.

[Whereupon, a brief recess was taken.]

Mr. FUQUA. I apologize for the disruption, but part of the problems we have around here is trying to conduct our business on the floor as well as in our committee rooms, so we have those periodic interruptions.

When we were interrupted we were talking about faculty and the operation of getting adequate faculty and the retention of adequate faculty and maybe our two witnesses from industry could elaborate on their perspective of why faculty is so attracted to industry. There's certain embodiments available in a university environment probably somewhat different than in industry and probably vice-versa. Maybe, Dr. Hirschmann, you could expand on that.

Dr. HIRSCHMANN. Thank you, Mr. Chairman. I would like to begin perhaps by agreeing that attempts to try to direct activities in certain directions is probably a very hazardous game, and this has been suggested by you and others here. Things change very often in a very unexpected way and if one seeks to predict what's going to be needed 10 years from now, one is likely to be quite wrong.

But, it is very clear to me that it is easier for us today to recruit really top-notch people than at any previous time in the 35 years that I have been at Merck. And I think there are several reasons which account for this. When I interview potential applicants, especially people who are very highly regarded by their professors, I very often ask them somewhat facetiously, why do you think you want to come here? Why don't you want to follow a distinguished academic career? And I think in the case of our industry I think there are several reasons. I believe that our young people today are very highly motivated. This has been true for a number of years now. And I believe that very many of them find the idea that they can do something relevant, maybe discover a drug that might cure a neighbor's child or what have you, is a very satisfying career. And I think that plays an important role.

Now, what the university has to offer is an opportunity to teach and surely that is a very rewarding opportunity as well. And I think what, in my view, the young Ph.D.'s and postdoctoral fellows are caught up in is this conflict that if they devote too much time to teaching, which is a very satisfying activity, their research is going to suffer. And if they don't publish they're not going to get tenure, and so that creates a problem for them.

A second reason why I think people come and like to go to a place like Merck is that the instrumentation which we provide is first rate. And while this is equally true at a relatively small number of our universities, at a great many universities this is not the case. And the cost of equipment has just gone out of sight and this is a problem in our universities.

The third reason, I think, is that the business of providing grant educations has really become a nightmare in many of our universities where faculty members spend an extraordinary amount of their time just worrying about grant applications. I have sat on the medicinal chemistry 30 section A of the NIH for a number of years and as funding for these grants was reduced, applications, which in previous years would surely have been funded because they were reviewed very favorably, were no longer funded because they were below the cutoff line. So, the concern about grants and funding is really a nightmare and ties in to the whole business of tenure.

I would like to express some concern about the fact that especially at a time when funding is tight, that too many faculty members write grant applications not because they want to work on a problem, but because they think it's going to be fundable. And I think this difference between university and industry, and I'd like to think that our top university scientists do research that they really want to do, and not because they think they're going to get a grant.

I would like to respectfully disagree with some of my academic friends here when they suggest that the workload is an issue why people go into industry because our workload is horrendous and to try to remain a viable scientist and attend countless committee meetings, which I do every day is a pretty bad proposition as well. So, I think the workload is not what's causing the problem, but I think some of the other issues may contribute.

Mr. **Fuqua**. Dr. Jamerson, would you care to comment?

Dr. **Jamerson**. I must concur with all of Dr. Hirschmann's points. And I can't add too much to those, as a matter of fact. I also talked to people that we interview for positions and ask them the same question about what about university positions versus industrial. I hear the same words regarding grants, the need for searching for grants, a lot of paperwork that they perceive professors get involved with, committee activites. They're very much impressed with the facilities in our laboratory. We make a very diligent effort to support our scientists and engineers with the very best equipment, and they see that when they interview with us. There is less of that in the universities and I've been to many universities and seen the shortages and the things they vary, in unique ways, put together to do their research. They also see outstanding scientists to collaborate with. And they see departments that are very close by so that their perception is an ease of collaboration with other people. In universities, professors tend to establish their own little groups and professors tend to be less prone to collaborate with others outside their field. But, we do have interdisciplinary research teams in industry.

We need to approach problems and scientific problems in a large measure from an interdisciplinary approach, and we do set up those kinds of organizations. And so those are some additional thoughts to Dr. Hirschmann's about that, but we pretty much agree.

Mr. **Fuqua**. Mr. Reid.

Mr. **Reid**. Mr. Chairman, I would like to again thank you and the staff for putting together these fine panels on the problem that's facing this country, namely the problem of scientists and engineers, how we can get more in all the fields. This, though, brings me to a question that I have. Dean Meier, you made a statement and I'm quoting directly, in fact I copied it off of your prepared statement. "The shortage of engineering faculty is real. It is critical and it is not just a problem with which the States must deal." You also said in your remarks to the committee that there is a critical Federal role that the Federal Government must play. And then as an example most everyone talked of, the need of the Federal Government to become involved. Dr. Zaffarano, you said that a Federal support program could be designed, on page 3 of your testimony, which brings me to a political question, and that is we have, sweeping the country today, a philosophy that Federal Government should stay out of everything—that if Federal Government has been involved, they shouldn't have been, and if the Federal Government is doing something, the States can do it better. And this philosophy isn't just something in the western part of the United States, it's all over the country. And I find it troubling because to me, in fact I heard Malcolm Baldrige at a meeting a couple of weeks ago in an off—the press wasn't there, but I guess it wasn't off the record, but Malcolm Baldrige said that many of the people he deals with don't realize that there is another economic text other than the *Wealth of Nations*, and that was written hundreds of years ago.

Now, I guess what I am saying is how do you match what all you gentlemen are stating with this dominant political statement that is in the country today that the Federal Government basically should stay out of everything and education is at the top of the list.

Dr. MEIER. I like the way he handed me the microphone. [Laughter.]

I would say that the States aren't dealing with this issue. There are two points, one is engineering colleges and their universities are national resources, they are not just State resources. I made that point and I believe that emphatically.

Second, the States are not dealing with this issue and, in fact, have proven themselves to be incapable of dealing with the issue in the sense that the funding, the vagaries of State funding are much more varied than those of Federal funding, and there needs to be more of a fundamental support base under these programs if we're going to be successful in what is international competition.

Mr. REID. But Dean, see I understand what you're saying and I do not disagree with what you're saying, but you're not answering my question. And my question is that let's say Chairman Fuqua and I went back to our States and we said: "People, we've got a real problem. Universities don't have enough Ph.D.'s to teach students, and some of these drug companies don't have enough Ph.D. candidates and doctors to draw from to properly meet their demands, therefore, what I have recommended in Congress is a multimillion- or maybe billion-dollar appropriation to, and you've all suggested ways we could do this." How do you think that would go over at home? They'd say, "Who cares?" You know, I think there is a basic—and I think part of the problem is that you may be educating each other, but I think you're doing a very poor job of educating the public because it leaves Chairman Fuqua and I in a position where the dominant political statement that is sweeping the country is that the Federal Government should stay out of everything, and you can come and talk among each other and say what an important role we have, but you're not making the statement perhaps to your State legislature. You're not making it certainly to your Members of Congress around the country, and I feel that you need to do more in educating each other and educating students that come into your institutions. I think that there is a real problem in that you're not helping us. Because Chairman Fuqua and I, I'll bet, we believe in what you're saying, but I could also guarantee you that we can't do this without some help outside these Halls of Congress.

Dr. MEIER. Well, I don't doubt what you say and I would agree with you that we have not done the kind of job that we should have done in educating the public. There is no question about that. I think though, that that is an issue that we in universities are beginning to address as directly as we can and I believe as well our technical and professional societies are attempting to do the same thing. So, I will agree with the indictment against us, but say that we are making an effort to try to rectify what are past sins.

Mr. REID. Dean, I'm wondering if any of the other members of the panel have some ideas and you know I am critical, but I am wishfully critical hoping that you can come up with some ideas that will make our job in this unique society we find ourselves in easier.

Dr. JAMERSON. Mr. Reid, let me take it from the following point of view. It seems to me that you have a fantastic opportunity in this task force to build for the future. And let me illustrate this in the following way. In the last century, the Congress of this United States made a marvelous decision. They set up the land-grant institutions in this country, which developed the agricultural base of this country, which led to the land of plenty, which brought in people from all over the world to build up our Nation. Are we not now asking the broad question, invest in science and technology to the extent that we invested in agriculture in the last century, to build for the 21st century? And perhaps we are just short of communicating that to the public at large. They don't understand the issue. We haven't been forceful enough and thoughtful enough in presenting this as a very major issue. I have with me a copy of the *Japan Economic Journal,* some of you may read this, and let me read an exerpt from June 25, 1985, issue: "The Japan Committee for Economic Development has recently compiled proposals for a new type of Japanese management to be adopted by business companies in Japan in the 1990's." And it has several specific points. "A shifting emphasis from the manufacturing department to the R&D department." The Japanese are getting more research oriented. They've been great innovators in terms of taking our basic discoveries and getting them into the marketplace. They are now emphasizing R&D. Second, from seniority to meritocracy, and, third, from a more homogeneous group to a more heterogeneous group.

What we're saying are some statements to the effect they they're going to move their society to be more like us, however, they are making a larger investment in R&D. And this is, much is throughout their industry and throughout their university structure. Perhaps the public at large doesn't appreciate this, that we're in an economic war in that in order to succeed in the future you have to invest in the future. And that's what developing Ph.D. talent is all about. That's developing B.S. and M.S. talent and utilizing that talent effectively. We're doing this in the automotive industry. We're teaching all of our workforce about statistical quality control. We have not done that in the past. We need everyone in our plants to understand some physical principles that they never have been asked to understand before. As this knowledge base grows, as we train our workforce, as we establish a higher technology in our production, and that become realized by the public at large, and you need to help us in that regard, then I think we're going to see an ability to convince the American public that the time is now to invest in the future because we have been shortsighted in the past in certain instances.

Mr. **Haddad**. I would like to point out that we have a marvelous diversity in this country of educational institutions. We have State-supported institutions, we have privated-supported institutions, we have research institutions, and we have essentially smaller nonresearch institutions. And that diversity, I believe, has lent us a great deal as a Nation. I think it far surpasses the educational systems that I'm aware of in other countries where there are such things as national universities, and there is no private support of higher education. I think that diversity opens up opportunities for a wide range of students from the brilliant to the less accomplished and I would hate to see anything destroy that diversity—if anything I think we need to preserve it and add to it. I believe it is a great strength of this Nation. I believe that when people complain about the problems in some of these schools that in thinking of solutions we should restrain ourselves from thinking of a panacea that would tend to level and homogenize our educational system.

Now, that may sound negative compared to what you're about, but on the other hand I think it is tremendously important and I believe that all of the things that Bill Meier and others have said are shortcomings with regard to the colleges, you know, equipment is very expensive and things of that nature, a lot of these things are going to have to be solved in a more indirect way by, for instance, I'm not necessarily recommending this, but rather than every college have every piece of equipment that it needs for graduate study, focusing on certain institutions, or certain regions, or having, you know, equipment supplied that can be shared by more than one institution.

I think when we talk about these second-tier institutions, the nonresearch institutions, the only mechanism right now that they have in order to keep their faculties fresh and vital for the future is their sabbatical program. Now, in industry, there is management development, and personnel development, and engineers, and scientists are given a chance to proceed with their own professional, technical development in an effort to keep them from getting obsolete. And I think, for instance, when I say that the benefits that accrue to the research institutions ought in some way to find their way to the nonresearch institutions, I don't necessarily mean by making the nonresearch institutions into research institutions. It's the benefits that we want to have from the research involved with the others, not necessarily by becoming research institutions.

How can you do some of these things? Well, you can do some of these things by having programs that would encourage the interchange of faculty between the research institutions and the nonresearch institutions, and there are various other mechanisms that I think we could develop.

But, the imporant thing is to try to preserve this wonderful heterogeneous diversity that we have in our educational system and improve it where it has weaknesses, but preserve it in its fundamental principle.

Mr. **Reid**. Dr. Zaffarano, did you have a statement?

Dr. **Zaffarano**. Yes, I would like to respond to your question. I want to answer that Government should not get out of everything. I don't think any of us is going to quarrel with the concept that the Government's primary responsibilty is to provide security for our people. There are two kinds of security and the kind of security we're talking about now is economic security, and I think it is quite apparent to me that economic security for the people in this country is going to depend very much on just what we're talking about today, scientific and engineering manpower—personpower, I'd better say. And I'd like to just reiterate my point. I think that the young people we have coming along, the brains with ideas for innovation who would desire to participate in these economic development problems we have, need to be encouraged to learn as much as they can about the problems, to learn the techniques of research, critical things. And my objective is to make this opportunity for, and of course I'm prejudiced, graduate education, available to all of those who want it and as I see it at the present time a national investment of funds to provide graduate education, support at the highest level for scientific and technical manpower, personpower, is a high priority item which the National Government, Federal Government, should be involved in.

Mr. **Reid**. Thank you very much. Mr. Chairman, just in closing, I'd like to make this statement that I serve on another committee, and I think many of the things that we deal with there are not nearly as weighty as the things that we deal with here. However, there is rarely a time that I go to that committee we don't have four or five rows of press attending with TV camaras. We're always on C-Span. Here we're rarely on C-Span, but yet there are things here that certainly, as you've indicated, Dr. Zaffarano, deal with the security of this country. And I would just like to make the charge to you, and certainly I would like to try to do my share, but I think each of you have an obligation to this country, if our security is involved, as we believe it is, to do a better job, somehow through the different societies you belong to, the educational institutions, the companies you work, to stress this point. We have to get the message to the American people or we're not going to be able to get the support here in this body that is needed to give the massive infusion of funds so that we can maintain our proper place in the world society today.

Thank you, Mr. Chairman.

Mr. **Fuqua**. Thank you, Mr. Reid. And let me thank our distinguished panelists for joining us today. We thank you very much. You've been very helpful and I think it's been a very, very worthwhile meeting this morning. Thank you very much.

[Whereupon, at 11:49 a.m., the task force recessed to reconvene on Tuesday, July 23, 1985, at 9:30 a.m.]

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SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

TUESDAY, JULY 23, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 9:33 a.m., in room 2318, Rayburn House Office Building, Hon. Doug Walgren (acting chairman of the task force) presiding.

Mr. Walgren. Good morning. I would like to welcome you to the continuation of these hearings on scientists, and engineers, and the problems of supply and demand.

As most of you know, these hearings are part of the larger science policy study that is being undertaken by a task force under the umbrella of the Science and Technology Committee.

Chairman Fuqua has a schedule conflict, and he would ask that his apologies be given to you for not being able to be here.

Our panel today consists of representatives from major professional and educational societies and they will be discussing the supply side of the marketplace with respect to previous testimony concerning employers' views of the workforce.

We are aware that the professional and educational societies do keep track of both sides of the supply-and-demand market in view of their interests and attempt to keep things in balance. In many cases, these societies collect the data and the statistics that can forecast the market's behavior as well as scrutinize the quality and the relevance of the education, and therefore your assessments of these areas are very valuable.

We have a panel of four witnesses today, and so, at the outset, I would simply say that your written testimony and any submissions you feel you would like to make in writing will be made part of the record without more and reproduced in full in that context and therefore be a part of a real reference source for those on the staff and other members who want to review and think carefully about the areas that you cover.

Concerning your verbal presentation, certainly you should feel free to emphasize and underscore the points that you feel really deserve to be made.

So, with that, let me say, just for the record, that there apparently is some interest in some photos at some point today, and under the rules of the committee, we need special permission for that, and that certainly is granted; that is no problem.

The witnesses, in order of their testimony—and then we will just proceed in this order—are Dr. Peter Yankwich, the provost of the University of Illinois, who represents today the American Chemical Society; Dr. Edward Lear, the executive director of the American Society for Engineering Education; Dr. David Challoner, the vice president for health affairs of the University of Florida, who will be representing the American Association of Medical Colleges; and Donald Weinert, the executive director of the National Society of Professional Engineers.

Welcome to the committee, gentlemen. Why don't we just proceed in that order, and we look forward to your testimony and the others to reviewing what we develop for the record here today.

Dr. Yankwich.

STATEMENT OF DR. PETER YANKWICH, PROVOST, UNIVERSITY OF ILLINOIS, URBANA, IL, ON BEHALF OF THE AMERICAN CHEMICAL SOCIETY

Dr. YANKWICH. Mr. Chairman and members of the Science Policy task force, my name is Peter E. Yankwich. I am testifying today as the chairman of the American Chemical Society's Task Force, which conducted a study of chemistry education in the United States. The work of this task force resulted in the October 1984 publication of the ACS report entitled *Tomorrow,* which I believe members of the committee and staff have before them. It is a volume bound in Stanford University's colors. I am pleased to summarize the findings and recommendations of this ACS report on the status of American chemistry education. I request that my written statement, together with the ACS *Tomorrow* report, be entered into the hearing record.

Mr. BOUCHER [as acting chairman]. Without objection, the statements of all the witnesses will be made a part of the record.

Dr. YANKWICH. My comments originate principally from my experience as a professional chemist, as a university research scientist, administrator, and teacher, and from my work for the American Chemical Society as a long-term member of its committees on education. Many of my comments will also reflect the views of experts in other areas of science and chemistry, since many of our problems are shared.

Science policy, for the Federal Government, must address the education of both the general public and professional scientists. Scientists work directly and indirectly with nonscientists. The work of scientists affects the lives of all citizens and is affected directly by decisions made by citizens. Any substantial inadequacy in the science education of nonscientists therefore weakens the performance of science.

The ACS task force studied the science education of both scientists and nonscientists. The education of today's professional scientist has been constructed with much care and with strong but sometimes inconsistent support from Federal and State Governments as well as from industry.

In order to maintain a viable education system, effective support must be applied in an orderly, consistent fashion over a substantial period of time. The parent committee of your task force calls lack of such consistency a "roller coaster" effect, and that term is well applied.

It appears that, today, high quality scientists are being produced in numbers that are reasonably satisfactory for the health and security of the Nation, but by no means does that imply that the effective education of scientists can be taken for granted. There are some deficiencies that must be addressed now, and maintenance of current levels of quality and performance will require vigorous action and, very likely, some additional resources.

A serious and especially pernicious problem in the education of today's scientists is the inadequacy of instrumentation available for teaching. Much of the work of scientists requires sophisticated instrumentation, and that situation is not likely to change in the foreseeable future.

Scientific instruments are expensive. Their prices range from a few thousand dollars to multiples of the annual salaries of professional scientists. Most instruments become obsolete after 7 or 8 years, and the costs of maintenance become excessive at that time. Yet that terminal age for the usefulness of instrumentation is equal to the average age of research and teaching instruments in academic institutions, according to a recent ACS survey. That survey showed an immediate need in current dollars for almost $160 million in new instrument purchases and an additional $540 million to update, maintain, and support the instrumentation used for just chemical research in the academic community. I am informed that the academic community contains, in addition, persons such as biologists, physicists, engineers, and others.

These estimates do not include the needs of 2-year colleges, a sometimes neglected sector of higher education which enrolls nearly half of all students taking chemistry courses. And the same is true of physics.

Current Federal programs seek to address this matter, but they need expansion, and more colleges should be made eligible for instrument purchase and maintenance funds. For example, against the figure of $160 million for purchases that I mentioned, the NSF fiscal years 1985 and 1986 budgets in the college science instrumentation subactivity contain appropriations under authorizations of only $5 million.

The findings summarized in the red *Tomorrow* report, which you have, on the education of nonscientists parallel in many respects those published in the report entitled *A Nation at Risk*, the highly publicized product of the National Commission on Excellence in Education; for example, misunderstanding of science is widespread; the public understanding of chemistry is especially poor; laboratory exercises are disappearing from the science education of students at both the high school and college levels; and, at all levels, applications of both discoveries about learning and of new information technologies are occurring haphazardly.

This situation directly affects the preparation of scientists in their formative years. It creates the atmosphere in which the scientist later does his or her professional work.

The American Chemical Society views this situation with such alarm that it has established staff offices and numerous programs for both high school and elementary education and anticipates substantial expansion of their duties in the next 5 years.

The ACS also seeks to work with consortia dedicated to improving science education, these consortia consisting of not only professional scientific organizations but representatives of industry and government as well.

The highest priority recommendations that the American Chemical Society makes to the U.S. Government have to do with improvements in the qualifications of teachers and in the quality of instruction, especially in the high schools. We believe that a broad spectrum of inservice workshops, short courses, and institutes for teachers offer the best hope for improving and maintaining the qualifications of those who teach at every level.

And just behind the high school in our priorities is not colleges, and universities, or postgraduate education, where you might think professional chemists would focus their attention, but the teaching that goes on in the elementary schools. The newest of the offices established by the ACS is an elementary school office.

Information and educational technologies offer great potential for improving science education for students of all ages and with every kind of interest. It is proposed that the U.S. Government establish or support the establishment of a demonstration research and development center oriented specifically to new instructional technologies, and the NSB Commission on Pre-College Education in Science, Technology, and Mathematics made a similar recommendation.

Potential for these technologies to make major contributions to the education of scientists and nonscientists is so great that they deserve much more support than has been provided in the past. Improving the productivity of our Nation's scientists requires maintenance and continual improvement of the educational process. Improving education costs money. There is no free lunch.

The U.S. Government need not—nay, should not—provide all the funds, nor be expected to. But the failure on the part of all of us to come forth with the necessary support will cost the nation a great deal in the future.

I hope that my comments and summary of the findings and recommendations of the ACS *Tomorrow* report are useful to the work of this Science Policy Task Force as it considers long-range policy for science and engineering education, both for future professionals and for the citizens those professionals will serve.

These remarks may seem to be somewhat tangential to today's specific concerns of the task force, supply and demand for professional scientists; but I assure you that their direct relevance is not difficult to demonstrate.

Thank you.

[The prepared statement of Dr. Yankwich follows:]

STATEMENT
of
DR. PETER E. YANKWICH
on behalf of the
AMERICAN CHEMICAL SOCIETY
to the
SCIENCE POLICY TASK FORCE
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
for the hearing on
SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND
TUESDAY, JULY 23, 1985

SUMMARY OF RECOMMENDATIONS

The analysis by the American Chemical Society's Task Force for the Study of Chemistry Education in the United States, published in the October 1984 ACS report, entitled "Tomorrow," substantiated many suspicions about the inadequate and deteriorating state of science education in the United States. It revealed that:

- the professional education of chemists, and of scientists, in general, was in better condition than anticipated; nevertheless,
- a crisis threatens us, and it results from the inadequate knowledge and understanding of science by the persons who work side-by-side with scientists and engineers, who provide the services required by a complex technological society, and who ultimately make the decisions in a democratic society;
- U.S. science education today is woefully inadequate to maintain a strong, technologically competitive society.

EDUCATING THE PROFESSIONAL

- INSTRUMENTATION - NSF and other agencies should not only support the purchase of instructional research instruments by colleges, but should include in the budgets for these programs additional funds to permit experimentation, demonstration, and implementation of cooperative mechanisms for providing maintenance and repair service for such equipment.

  Federal programs should support instrumentation needs and the improvement of laboratory facilities for undergraduate teaching and research.
- FACILITIES - NSF should assess the country's current and projected need for new or renovated scientific facilities.
- ELECTRO-OPTICAL TECHNOLOGICAL SYSTEMS - Federal agencies should devote substantial resources to the experimental development, testing, and evaluation of electro-optical technological systems for providing maintenance, completion, and proficiency-acquisition types of continuing education, with special emphasis on the accessibility of high quality instruction to individuals away from the workplace.

EDUCATING THE SUPPORT BASE

- TEACHERS - A vigorous and large expansion of NSF and other federal programs is required to upgrade the quality of science instruction through direct service to teachers. State and local governments should match the federal contribution by facilitating and supporting teacher participation in such programs and, in due course, by developing their own systems for assuring teacher improvement and revitalization.

- INFORMATIONAL TECHNOLOGY - The federal government should continue and expand its role as a major supporter of research and development in the use of computers and other information technologies in science education, including the establishment of a research and development center to explore the potential of information technology in science education.

- BASIC RESEARCH IN SCIENCE EDUCATION - The federal government should continue and expand its role as the principal supporter of basic research in science education, especially through efforts that increase the interaction between and among scientists, science teachers, and cognitive scientists.

My name is Peter E. Yankwich. I am testifying as Chairman of the American Chemical Society's Task Force which conducted the Study of Chemistry Education in the United States. The work of this Task Force resulted in the October 1984 publication of the ACS report, entitled "Tomorrow." I request that my written statement together with the ACS "Tomorrow" report (APPENDIX) be entered into this hearing record.

The American Chemical Society, a nonprofit scientific and educational organization with a membership of over 135,000 chemists and chemical engineers, is concerned about the status and effectiveness of the nation's science and engineering education programs. I have been for many years a member of the ACS Committee on Education.

Motivated by the concerns of its own education committees, numerous reports on American education, and an intensive study of chemistry research by the National Academy of Sciences, the American Chemical Society carried out its own analysis of chemistry education in the United States, resulting in the publication of the ACS "Tomorrow" report. The analysis, with recommendations for rectifying identified problems in chemistry education, was completed by the ACS Task Force of expert individuals from many different backgrounds in chemistry. These persons brought to the Task Force not only high chemistry literacy but an intimate knowledge of one or more of the factors affecting, or affected by, the delivery and results of chemistry instruction. The backgrounds of the Task Force members included educational experience (administration of school systems; classroom teaching at elementary, high school, and college levels; pre-service and in-service teacher preparation; curriculum and materials development; etc;) and experiences as working professionals in the chemical research, development, and production activities of industry.

At the start, the Task Force was advised to concentrate its attention on post-secondary chemistry education, with special emphasis on the undergraduate and graduate preparation of chemical scientists and on their continuing professional education. Soon, however, many urged the Task Force to broaden the scope of the study, expressing the conviction that the education of nonscientists and critical problems in precollege education were equally deserving of its efforts. Ultimately, the Task Force looked at all education in chemistry--kindergarten through postdoctoral professional.

The ACS Task Force members believe that the study of the universe and of the creatures that occupy it, that is, the study of science, has increased in depth and penetration in recent years and its results are changing our lives at an ever-increasing rate; but, education in science and technical fields has weakened and fallen behind the pace of application. The disparity has become intense and critical in the last twenty years. There are effective means that can be employed to restore the educational system to a viable state where it can serve more effectively the objectives for which it is designed and supported, but those means must be employed in an orderly, consistent fashion over a substantial period of time. In order to accomplish this goal, the Task Force called upon units within the ACS to establish certain bodies, task forces, and staff offices to undertake educational studies and projects; it asked the chemical industry for resources to sustain the educational programs on which the future of industry must depend; and it called on the state and federal governments to devote substantial additional resources to the improvement of education.

The analysis by the ACS Task Force substantiated many suspicions about the inadequate and deteriorating state of science education in the United States. However, it also revealed that the professional education of chemists, and of scientists in general, was in better condition than anticipated. Certainly, improvements in the education of scientific manpower are needed and major efforts must be exerted even to maintain the present level of quality. Nevertheless, a crisis threatens us, and it results from the inadequate knowledge and understanding of science by the persons who work side-by-side with scientists and engineers, who provide the services required by a complex technological society, and who ultimately make the decisions in a democratic society. U.S. science education today is woefully inadequate to maintain a strong, technologically competitive society; and that would be true even if no problems existed in the education of professional scientists and engineers.

EDUCATING THE PROFESSIONAL

In the ten years following 1971, the decline in degree production in the physical sciences, including chemistry, has been about 10% at any level. In 1980-81, there were approximately 10,000 baccalaureate degrees awarded in chemistry, 1,800 masters, and 1,600 doctorates. For all physical sciences, the corresponding numbers were 21,000, 5,500, and 3,600, respectively. Many employers of scientists find their needs being relatively well addressed in both quality and quantity by the products of American colleges and universities, but there are several problem areas which need to be addressed.

INSTRUMENTATION

The National Science Foundation and other agencies should not only support the purchase of instructional research instruments by colleges, but should include in the budgets for these programs additional funds to permit experimentation, demonstration, and implementation of cooperative mechanisms for providing maintenance and repair service for such equipment.

There is concern that both the quantity and quality of laboratory experience in baccalaureate degree programs are decreasing. The requirements for formal laboratory work have always been less in the United States than in other industrialized nations, but increasing costs of modernization, upgrading, or even sustaining present levels of quality generate pressures, which are resulting in even less favorable comparisons than before. Many students awarded bachelor's degrees in a science have very limited experience with modern laboratory techniques and even less experience in the design, formulation, conduct, and analysis of experiments. As the content of the science curricula has become more theoretical, more student time is spent in the classroom and in the pursuit of solutions to formal problems, and less in the laboratory learning and perfecting those techniques which establish and maintain the real contact of a scientist with the material world. Students develop little feeling for the behavior of matter--which, ultimately, is what science is all about.

For over twenty years, one of the most effective responses of science educators to the disinclination of students to regard laboratory work as important has been to bring such supervised experimentation closer in methodology and sophistication to the ways that science is practiced in career situations. At first, experiments in advanced courses were designed to use instrumentation like that used in academic or industrial research; later, less expensive and more sophisticated versions of these instruments became available to less advanced courses. The cost escalation of the past ten to fifteen years threatens to wipe out these earlier gains, thus reducing the quality of preparation for professional work.

The initial cost problem was attacked successfully by a host of programs to support educational facilities. These include such activities as industrial donation of still useful instruments and instrument purchase programs supported generously in past years by the National Science Foundation. Instructional and research instrumentation programs for colleges and universities have improved laboratory instruction, as have those programs which stimulate and support undergraduate and faculty research opportunities. Invigoration and expansion of these programs are necessary if the future U.S. science graduate is to be capable of practicing and not just contemplating science.

A 1982 survey by the ACS Committee on Science--"Instrumentation Needs of Academic Departments of Chemistry"--found that the average age of the instrumentation in U.S chemistry departments was between eight and nine years. Based on the experience of laboratory managers, retaining most instrumentation beyond seven or eight years is unwise. Given new developments in the field, instruments continuously become scientifically and technologically obsolete. The ACS survey results also indicated that fifteen percent of the equipment at small chemistry departments, and nine percent at major ones, were not fully operational in 1982. Maintenance of equipment becomes a serious and costly problem as the age of equipment increases.

The ability of chemists in academe to conduct research at the cutting edge of science is limited by the age and condition of their equipment. The ACS estimated (1985 dollars) that the one hundred major U.S. chemistry departments would need $89.8 million for instrument purchases; and that 470 smaller chemistry departments would need $70.7 million. The Society projected that with the addition of maintenance, technical support, and other ancillary costs, $540 million may be required to update and maintain equipment in a manner necessary to ensure progress in chemical research. The need, as estimated in the ACS survey, is so great that both private sources and government programs must be utilized to address this problem.

The ACS is aware of the National Science Foundation's continued support for predominantly undergraduate institutions through its research directorates. However, a problem which is inadequately addressed is modernization of undergraduate chemistry laboratories. Since these departments are the source of candidates for graduate work in chemistry, as well as the training ground for many entry level professionals, federal programs should support instrumentation needs and the improvement of laboratory facilities for undergraduate teaching and research.

FACILITIES

In the past, campus "bricks and mortar" has been the joint responsibility of the public and private sectors. Academic institutions have obtained funding from a variety of sources--alumni funds, corporate grants, foundation grants, and federal government awards. The American Chemical Society believes this should be the continuing pattern of obtaining facilities funding. No one should expect the federal government to solve this problem single-handedly.

The exact magnitude of the facilities problem is not known, but there is a large and growing recognition of the need for funds to build and restore scientific research and education facilities. The ACS recommends that NSF assess the country's current and projected need for new or renovated scientific facilities. Once such a nationwide assessment has been done, it can serve as a guideline for the consideration of future requests. The National Science Foundation currently administers the data collection for instrumentation needs at universities. A similar data base should be assembled and maintained to assess future needs for university science facilities.

Although it is difficult to determine the scope of the facilities problem, it needs to be addressed now. One method of dealing with the immediate problems in this area would be to initiate a renovation program rather than to rely on funds for new starts. Renovation funds should be used for modernizing the necessary safety features, such as fume hoods, needed in both research and teaching laboratories. The Society notes with extreme interest the "University Research Revitalization Act" (H.R.2823), recently introduced by Congressman Fuqua, which would fund renovation as well as new starts. This bill also mandates NSF to conduct the type of facilities assessment that the ACS believes is necessary for the future health and well-being of science education. The ACS is in the process of formulating its comments on H.R.2823 for presentation to the committees considering this legislation.

ELECTRO-OPTICAL TECHNOLOGICAL SYSTEMS

Federal agencies should devote substantial resources to the experimental development, testing, and evaluation of electro-optical technological systems for providing maintenance, completion, and proficiency-acquisition types of continuing education, with special emphasis on the accessibility of high quality instruction to individuals away from the workplace.

The tradition of continuing personal and professional education is a very old one in the U.S. It has been sustained by the involvement not only of educational institutions but of professional societies, licensing boards, employer entities and groups, and individual providers. The purposes of such continuing education are almost as numerous as the individuals so engaged; but, the major categories, apart from cultural and educational enrichment in service of personal objectives, appear to be:

Maintenance: typically courses intended to maintain and update the previous formal education of the individual;

Completion: usually courses (in both major and minor fields of study) in areas which complement or supplement the work done by the individual student;

Proficiency acquisition: work designed to yield (through limited, often intense study) new or enhanced proficiencies in the use of new experimental techniques; report writing and technical communication; recent advances in methods, theory, and practice.

Continuing education is accomplished through a variety of formats: "open university"; correspondence; typical pre-college and university classes; less formal modes which involve just the individual student at the time of instruction; and tutorial and small group instruction. Twenty-five years ago, continuing education, like initial education, was delivered primarily through the printed or directly spoken word. More recently, electro-optical techniques have gained prominence--prerecorded audio and video materials, electronic blackboard and teleconferencing, and a number of different kinds of interactive, computer-based methods--favoring classroom or institutional settings.

The rapidly spreading use of electro-optical techniques, unlike the "blip" of teaching machines some years ago, exhibits such momentum that one must conclude that a revolution in educational technology is underway which will be as sweeping as that occurring in the workplace. Such a revolution must extend to techniques affordable by individuals so that continuing education can take place at home as well as at work.

EDUCATING THE SUPPORT BASE

TEACHERS

At too many places, at too many levels, teachers are ill-qualified to teach science. Elementary school teachers often have had no serious science instruction in their preparation for the profession. At the high school level, few who teach chemistry or physics have real competence in the subject matter, and those who do are increasingly attracted to other professional employment. In both the high schools and small colleges, too many faculty members are forced into an instructional pentathlon--spread thin over so many unrelated assignments that they are unable to provide quality performance in any of them. There is very little organized help for teachers at any level who want to maintain or improve their competence to give instruction in a science discipline, chemistry included.

Curriculum materials of high quality and demonstrable effectiveness do not exist in profusion; the lower the grade level the greater the need. Marketing forces push instructional materials toward conformity and uniformity, with the predictable result that neither diversity nor excellence is found or served. The computer, instead of liberating instruction, may often put it into a straitjacket--conveying subtly, for example, the false notion that science is all known and closed instead of exploratory and open-ended. Laboratory exercises, in part because they are logistically difficult and have always been expensive, are being seen more and more often as unnecessary. Students are expected to learn from watching someone else's "hands on" experience instead of their own.

A vigorous and large expansion of National Science Foundation and other federal programs is required to upgrade the quality of science instruction through direct service to teachers. Such programs should include not only college and high school faculty members (who were well served by earlier programs of the Foundation) but also elementary school teachers and those specialists in science education at all levels who will bear responsibility in improving the science literacy of students and the general population. State and local governments should match the federal contribution by facilitating and supporting teacher participation in such programs and, in due course, by developing their own systems for assuring teacher improvement and revitalization.

Our society must insist on quality--in particular on the high quality of the educational experiences that students have. Good teachers must know something about the teaching arts AND about what they teach. It is important that there be a continuing national effort to sustain teacher vitality and to motivate the changes in chemistry education at all levels. This is necessary to respond to the continuous development and change in the discipline.

INFORMATIONAL TECHNOLOGY

The federal government should continue and expand its role as a major supporter of research and development in the use of computers and other information technologies in science education, including the establishment of a research and development center to explore the potential of information technology in science education.

Modern information technology, such as computers, video recording devices, and inexpensive electro-optical means of storing and transmitting information, is creating a wide-reaching revolution in the conduct and even the nature of human affairs. The computer is quickly and drastically changing the nature of many jobs as well as the ways in which commerce and industry are conducted. It has enhanced greatly the effectiveness of scientists and expanded the scope of scientific investigation.

The environment created by the computer makes new demands on science education but, fortunately, often affords the means to meet these and other educational needs. The range of computer applications to science education is enormous: simulations of the behavior of chemical systems; mammoth data base capacity; networking of individuals, libraries, and data bases; diagnosis of the individual student's current knowledge, mental models, and problem-solving strategies, which permit teacher-tailoring of appropriate learning activities; tireless tutoring; etc. The whole science curriculum, from elementary school onward, must be changed to prepare students to use computers at work and at home as well as in the classroom and laboratory.

The changes in school programs that can be made because of these applications should not be easily or lightly undertaken. All of them, to some extent, put the student and teacher at the mercy of the programmer. For example, simulations assume that the programmer knows what is going to happen, and diagnosis is based on the programmer's knowledge of syndromes and of judgments concerning their elements. Schools must have guidance based on research and development if they are to be confident of the educational effectiveness of various innovations now possible and if advanced possibilities that go well beyond present practice are to be explored carefully. Some of the necessary research and development will be carried out in the private sector. But, since private and public purposes do not always coincide, there is a need for the federal government to provide support as it does in other areas important to the national interest.

At present, the National Science Foundation and the National Institute of Education are the main federal vehicles of support for basic research in science education. The Department of Defense and other federal agencies, however, may be sponsoring research and development that has substantial application to educational information technology. These agencies should increase the number and expand the support of joint or cooperative research projects that bring together physical and life scientists, teachers, computer scientists, and cognitive scientists to study and develop new applications in this area. Because of the number of different disciplines involved in such activity, the American Chemical Society proposes that the federal government establish a demonstration research and development center to explore the potential of information technology in science education for all students.

BASIC RESEARCH IN SCIENCE EDUCATION

The federal government should continue and expand its role as the principal supporter of basic research in science education, especially through efforts that increase the interaction between and among scientists, science educators, and cognitive scientists.

Research in cognitive science is yielding knowledge that can improve the learning of science by the general student and the student interested in a science-related career. For example, cognitive scientists, in collaboration with scientists and teachers in several disciplines, have shown that students enter science instruction with their own mental models of the phenomena that are studied. These models, based on previous observation and experience, are often erroneous, are remarkably resistant to modification, and often remain dominant even after science instruction has been completed.

Research in this area strongly suggests that substantial modifications are required in existing curricula, teaching practices, and teacher education programs, if learning of science is to be improved. It is in the national interest that these changes be made and that further research along these promising new directions be supported by the federal government.

THE COSTS

We cannot estimate the costs associated with a system of science and engineering education that does not keep pace in quality and opportunity with that offered in other industrial nations. We cannot estimate the costs associated with less than well-informed citizen judgments, continued low standards of teacher certification, obsolete instruction and teaching materials, failure to assist teachers to improve their qualifications or any of a host of consequences of inattention to the centrality of science in education for life in today's world or tomorrow's. But those costs--the costs of falling short--are surely very high.

As you may already know, the National Charter of the American Chemical Society imposes an obligation upon the ACS to provide assistance to the government in matters of national concern. One of the objectives of the Society's federal charter is the promotion of research and the advancement of education. It is hoped that this summary of the findings and recommendations of the ACS "Tomorrow" report will be useful to the work of the House Task Force on Science Policy as it considers long-range policy for education in science and engineering--both for future professionals and for the citizens those professionals will serve.

Mr. BOUCHER. Thank you, Dr. Yankwich.

Dr. Lear.

STATEMENT OF DR. W. EDWARD LEAR, EXECUTIVE DIRECTOR, THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION, WASHINGTON, DC

Dr. LEAR. Thank you, Mr. Chairman.

I should like, in the time we have available, just to highlight a few points from my written testimony.

First, let me say that I represent the American Society for Engineering Education, which is rather unique in that the engineering profession is the only one, to my knowledge, anyway, which has a society dedicated solely to the education of people for the profession. We have a membership of individuals, largely the faculty members of the colleges of engineering and engineering technology throughout the Nation, but a variety of institutional memberships, industrial being one of them, of course, from about 125 major corporations which have products and services which are technology based and, therefore, have a strong interest in an engineering workforce that is of adequate numbers and of adequate competence. The engineering colleges themselves and engineering technology colleges of the Nation are institutional members and most of the major engineering societies—Mr. Weinert's society, the National Society of Professional Engineers—along with the disciplinary societies in electrical, mechanical, and so on, and finally, a few Government agencies. So we are a mixed bag, in a sense, but a group of individuals and entities which have a common interest in seeing quality engineering education in the Nation.

I would like first to address an issue which is of primary importance, germane, certainly, to the work of this task force, and that is, why should the Federal Government be involved in engineering education specifically, as opposed to education for specific disciplines of many other kinds which we might cite?

I think the answers are straightforward. I see three of them primarily. The first is that the Federal Government is an extremely large employer of engineers and therefore, in that role, has a high stake in ensuring that there are adequate numbers of qualified people available.

Don Weinert and I served on a committee recently, incidentally, of the National Research Council, which turned out a report, *The Education and Utilization of the Engineer*, which I am sure you have seen. We took on the task of looking at the Federal involvement in employment of engineers and found that about 30 percent of all the 1½ million engineers out there in the workforce are either directly or indirectly on the payroll of the Federal Government.

That means people who work directly for the agencies and for the services, but also those who are in the jobs that require engineering jobs in the prime contractors for the Government. This does not go to the secondary and tertiary contractors, so I am sure there are quite a few more involved under the Federal wing. So it is a point of prime concern to the Federal Government, obviously.

The second issue is one having to do with the national well-being, which is a Federal responsibility, a Federal concern, certainly, and that includes economic well-being and the issue of industrial competitiveness, which we talk so much about, which leans so heavily on a strong technology base, which again leans heavily on a strong engineering workforce, a well-qualified engineering workforce.

And, finally, another issue of national well-being, the security of the Nation, the military preparedness, which in today's world has systems almost universally which use modern technology, and sometimes technology on the cutting edge of a particular discipline.

So, for all these reasons, I hope it is obvious that the Federal Government has an extremely strong stake in ensuring the well-being of engineering education. With that as a given, what does Federal policy which has engineering education as a prime concern mean?

I would like right at the very outset to say I do not see it as meaning that the Federal Government steps in in times of crisis and, with crisis-type programs, bails out an area, whether it is engineering education or whatever it happens to be.

As most of you know, we are in a set of deep problems in engineering education now which, I feel, with adequate Federal policy over the years past—and this is conjecture, because I don't have any documentation of anything of this sort—but with Federal policy which, for example, had adequate numbers recognizing the marketplace in terms of fellowship support for graduate students in engineering over years past, in terms of support for equipment and facilities, all of which, with appropriate programs which leveraged the partnership between the Federal Government and the private sector and the universities themselves. If there had been a recognition that the fundamental engineering research which is carried on by the engineering colleges—which is between that spectrum of basic research and applied work in the industrial world—if that had been recognized as a basic responsibility of the National Science Foundation over the years, for example, I feel confident,

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with all of those, that we wouldn't be in the position we are in right now. Now, as I say, that is conjecture.

But this is not at all, in any sense, to put any blame on the Federal establishment or any part of it for not having the clairvoyance to anticipate these problems—many of us in the system itself did not anticipate the depth of the problems—but simply to say that an active policy of concern about any particular area circumvents the development of the problems and prevents our having to act in a firefighting mode when the ox is in the ditch rather than keeping the system healthy all along.

In fact that, to me, is the essence of what Federal policy's concern about any area means. It is how we ensure that the system is healthy and that we get the very best out of it that we can get, how we nurture it, and how we also ensure that all the players who should be involved in that system besides the Federal Government itself—the private sector and others—are involved to the extent that they should be involved.

I would like to close my comments with a suggestion of a partnership which I see being created and, hopefully, one which will flourish between the work of this Science Policy Task Force and a program which we have under way in our Society, which is described in some detail in the appendix to my written testimony, and that is our Quality of Engineering Education Project. This is a rather unique partnership between industry and education in which 28 major corporations are funding a program not only with their money but with their people, very heavily involved with the four task forces which are addressing areas of concern for the quality of education and the future of engineering education, and with their involvement in an advisory board for this whole program, which is a 2-year program which will culminate just about the time the work of your task force culminates.

What we are looking at are four things: One, very briefly, the undergraduate engineering laboratory issue, where we are headed with that, not only in terms of the equipment needs but the whole place of laboratory instruction in the scheme of things in the engineering education of the future.

A very interesting and very exciting area but one which needs a great deal of thought and contemplation on where we are going is what is the future of the use of educational technology in the engineering education process. We are speaking primarily of the microcomputer, but we have lots of other technology that is available to us now. How do we best use that? Does every school have to invent its own wheel? We hope to come up with some answers on that score which will be of use to the engineering education community nationally.

A third issue is how the engineering faculty stay alive, both technically and pedagogically, in a world where the technology is changing so rapidly that the knowledge base on which the teaching is laid for the engineering professor is like the sands of time: it is continually shifting. How do you keep people abreast of the times in a situation of that sort on a national level, not on an ad hoc level?

And, finally, we are looking at an issue we have never looked at before, and that is, what kind of preparation do we want for people who are going into the teaching of engineering? What should their backgrounds be? What should their characteristics be? And is the system we have now the best one we can design?

Well, the reason I tell you about this is because we are going to come out in September 1986, if all goes well, with a report with a set of recommendations from each one of these task forces, and in those recommendations will be some for government. I assure that this is not going to be a litany of new programs for government. What we are hoping to do is to look at the current situation and see how we can do things better than we are doing with what we have to work with.

But specifically, if, in the results of your Science Policy Task Force deliberations, you come out with a recommendation that engineering education is a strong component of concern for the Federal Government—and we certainly hope that that will be the case—we believe that we will have some things which will dovetail into that in the way of programmatic actions to make that possible.

Thank you.

[The prepared statement of Dr. Lear follows:]

The American Society for Engineering Education

Testimony before
the

Science Policy Task Force
U.S. House of Representatives

June 23, 1985

DR. W. EDWARD LEAR
Executive Director

Chairman Fuqua and members of the Task Force:

Good morning. I'd like to thank you for inviting me here today to offer my thoughts on the federal government's role in a healthy engineering education enterprise. These are challenging times for our country's engineering schools and I appreciate the opportunity to participate in the science policy study on their behalf.

The American Society for Engineering Education draws its membership from a spectrum of individuals and groups which share a deep concern for the health of the country's engineering education system. Members include the professional engineering societies, over 125 engineering-oriented industries, several government agencies, and over 10,000 individuals, most of whom are faculty. In addition, the more than 250 accredited engineering schools of the nation belong to ASEE and find special representation through the Engineering Deans Council, the official national organization of the deans of engineering. The entire membership of ASEE is bound together by a common interest in assuring that this country's future engineers receive the finest education available.

I speak today not only as the Executive Director of ASEE, but as an engineering educator of more than thirty years experience, fifteen of which were spent as the dean of engineering at the University of Alabama (1966-1981). I also had the honor of directing the Engineering Division of the National Science Foundation from 1964-1966 and of working as a consultant with the House Science and Technology Committee in 1978. The majority of my time currently is spent overseeing ASEE's Quality of Engineering Education Project (QEEP), a two-year study funded by industry of four critical topics in engineering education. I will talk about the QEEP study in more detail later in my testimony.

In order to talk intelligently about the role, if any, that the federal government should play in engineering education I think it would first be useful to talk a little about the goals of engineering education. By understanding where engineering and the education of engineers fits into the spectrum of this country's activities we can better assess what needs to be done and by whom.

The field of engineering and the engineers who practice across its more than two dozen disciplines make an incalculable contribution to this country's social, economic, and military strength. Strong national security, an improved standard of living, and unchallenged world technological leadership are obvious benefits to be had from a healthy U.S. engineering enterprise. The global economic contest in which we find ourselves is here to stay. We can no longer depend on our vast natural resources to overwhelm the competition. Our enviable cultural traditions of academic and economic freedom prohibit us from copying wholesale some of the sharply-focused methods employed by our most formidable challengers. We will be called upon more and more to use our classic Yankee ingenuity to maintain our competitive edge. The innovative talents of our engineering community will be the mainstay of our future success.

As we become increasingly technology-oriented as a culture and as an economy our engineering schools will be challenged as never before to turn out the innovative people and research that will keep us on top. Maintaining a quality educational and research environment will become an ever more pressing priority.

What comprises 'quality' in engineering education? A quality education, in general terms, to me means providing the opportunity for an individual to realize his or her potential. My own definition of a quality engineering education would have a graduate walk away on commencement day with a kit of technical tools allowing the owner to swing with changes in technology. He or she would also have a basic grounding in the humanities and social sciences as well as an understanding of our economic and political systems. A graduating engineer would be able to communicate to technical and non-technical audiences. Understanding that 'change is the norm' would be an overarching theme.

Perhaps the best measure of the quality of engineering education which schools seek to provide their students is to be found in the 'value-added' to graduates after four years of schooling. Considering that two-thirds of the country's 1.5 million engineers do not go beyond the B.S. degree, but go straight into practice, what should a B.S. in engineering mean? I think that graduates should have gained an 'engineering approach' to problem-solving: know how to define a problem, identify its components, and approach a solution in a systematic fashion. They should also know that there are trade-offs --

few engineering systems are perfect AND feasible -- and know what can be done economically and practically to solve the problem. New engineers should also understand risk-assessment and be able to determine an acceptable degree of risk in their work. The innovative capability -- 'intellectual entrepreneurship' -- of our young engineers should also be developed and nurtured in our university labs and classrooms. Adaptibility and a commitment to life-long learning are going to be fundamental to an engineer's success in an increasingly interdisciplinary and fast-paced environment and should be instilled early on in his or her training.

None of the above comes without the commitment and resources to provide a grade-A learning environment. Therefore, it is also an important goal of the schools to maintain the top-flight people and tools necessary to see that students get the most 'value-added' for their time, money, and effort. Keeping both students and faculty on the cutting edge of latest technology is a particular challenge. The dynamic relationship of teaching and research becomes very important here. Research can keep a faculty member vital while providing an opportunity for students to learn from direct experience. Maintaining a quality faculty and research facility has become increasingly difficult in recent years in the face of high enrollments and other factors, and their critical importance to the quality of education will keep them at the top of every dean's priority list far into the future.

That last comment leads me to the next issue I'd like to share some thoughts on. What are the problems facing engineering education? Particularly in light of comments by the industries which hire our product that they're seeing the best quality graduates ever?

First, I think it's important to note that the two perceptions -- industry's and academe's -- are not contradictory, despite initial appearances. Industry IS getting the best graduates they've ever seen because the schools are getting the best freshmen THEY'VE ever seen. Engineering is such a popular field to study that most schools have had to limit enrollments to cope. As a result, we're getting the cream of the crop. These kids are so bright and so motivated that it would be pretty hard to keep them from learning even if we tried. They're rising above the cracks in the system and walking out in good shape.

I think the real question that is somewhat obscured by our current apparent success revolves around the 'value-added' component of the educational process. When you start with a great student you can still turn out a pretty good graduate, in spite of yourself. But that's not the point, for two major reasons. One, if and when enrollment in engineering goes down -- and with it the high quality of student -- a mediocre to poor system will not be adequate to produce an acceptable product. Two, even if enrollments stay steady (despite demographics), we do a serious disservice to those best and brightest who make it into the programs by not providing them the highest quality education -- "the opportunity to realize their potential". Even now there is concern about the innovative capability of our best graduates. Their technical competence is basically fine, but lack of design courses and meaningful laboratory experience because of overcrowded classes quickly shows in the field. Imagine just for a moment what would happen to the engineering capacity of this country if we really did justice to the raw talent entering our schools.

The main problem facing schools right now focuses on providing that quality educational experience so important to making the most of our students. Foremost in the academic engineering community's collective mind is the continuing critical shortage of qualified faculty. ASEE has taken a very active role in gathering data on the shortage and, in fact, undertook a two-year study of the problem in 1981. The project sought to document the extent of the shortage and the forces causing it. That effort, the Engineering College Faculty Shortage Project, culminated in a report in November, 1983. I have included a copy of that report in the appendix to my testimony. I have also included follow-up articles on the shortage which are based on data gathered for the years 1982 and 1983. You may well be familiar with the latest faculty shortage statistics -- 8.5% of all faculty posts waiting to be filled by qualified people. That percentage becomes an astounding 23% to achieve the optimal student-faculty ratio of the late 1960's.

A number of factors are contributing to this debilitating lack of qualified faculty. The theme tying these factors together seems to be the relative unattractiveness of an academic career. I think we're all basically aware of the disincentives for bright, young graduates to pursue faculty careers. Sparse graduate support, obsolete university facilities and equipment in laboratories, the lure of higher pay and more advanced equipment in industry, and overcrowded labs and classrooms are just a few of the more obvious negatives. Allow me, however, to let the graduates speak for themselves.

As part of the Engineering College Faculty Shortage Project a survey was done of a representative pool of the Tau Beta Pi (the engineering honor society) graduates from the classes of 1977 and 1982. These exceptionally well-qualified graduates are perceived to be among those most likely to pursue academic careers. The survey sought to collect their feelings and choices concerning graduate study, employment and teaching. The results were most revealing.

Of the Class of '82 only 7.4% selected engineering education as a "career goal". Of the Class of '77 only 2.0% were involved in engineering teaching as of the time of the 1982 survey. The new '82 B.S. holders also indicated that 29% of them would pursue engineering graduate study, but 75% of that group made it clear that an academic career was not planned. If that remaining 25% who showed an intention to follow a teaching career are 'derailed' in one way or another while pursuing their advanced degrees, that already small pool of potential faculty will decrease even more.

The Class of '77 respondents to the Tau Beta Pi survey were highly vocal. Over half provided unsolicited commentary on their choices of career. Their comments are interesting. Among the reasons cited are the following, in relative order of frequency: desire to work on 'real-world' problems; teaching would require a Ph.D. with low faculty salary and poor faculty benefits; desire to gain industrial experience; graduate school too expensive/no decent fellowships available/can't afford to go full-time; tired of being poor, broke all the time; industry provides better professional growth.

I'd like to quote from two letters received during the survey. The first is from a member of the Class of '77:

> "I feel compelled to supply you with a little more information than you requested on your enclosed survey. I am, and always have been, interested in teaching at a college or university. However, the requirement to obtain a Ph.D. in order to be a professor at a university has deterred me. The cost-to-benefit ratio, not solely measured in dollars, to me was not very encouraging. An investment of a minimum of three more years in a Ph.D. program and the generally low salary ranges for university professors was not an exciting prospect..."

From the Class of '82:

> "I will almost certainly NOT pursue a Ph.D. full-time due to a) high industrial salaries, b) uncertainty about my desire to teach, c) comparatively low fellowship support, and d) lack of role models."

To hear such an overall negative view of academic careers from the highest-caliber group of engineering graduates should make a profound impression on all who are concerned with the future quality of our engineering schools. We're not drawing our faculty from the top 10% of our classes as we did in the past; only a quarter of our sparse Ph.D. population is going into academe, down from one-third. Also, foreign nationals are NOT part of the problem; we can't blame them for our own inability to attract U.S. citizens into academe.

Support is clearly an issue in attracting graduates into graduate study and further on into teaching as a career. It's important to note that support for the average graduate student or post-doc is very limited. This is the pool from which we must draw our future faculty. The number of federal fellowships for science and engineering is only a fraction of what it was in 1968. NSF fellowhips stipends have been adjusted to some degree for inflation but the cost-of-education allowance has not. The level of fellowships clearly must reflect the marketplace and costs of the times. And we must keep in min that high loan burdens can't be made up on a faculty salary. All of these are contributing factors to dissuading our brightest graduates from pursuing academic careers. The result in the long run will be a small and possibly mediocre faculty struggling to produce high-quality graduates.

Also tied in with the issue of support is the poorly-recognized fact that half of our B.S. graduates, most of whom go directly into practice are produced by "non-research" schools. Keeping these faculty alive professionally without a significant and creative research element is difficult and potentially shortchanges students by exposing them to out-of-date faculty and NOT exposing them to 'real-world' engineering practice. Not only do they perhaps receive a less complete education, but little incentive exists for them to pursue academic careers themselves.

This clear crisis in quality human resources for our schools, combined with the appalling condition of our university laboratories, does not bode well for the future of engineering education.

Let me move on now to the theme of the Task Force's work: federal science policy. For the most part the federal government thus far has not played a planned role in the shaping of engineering education in this country. Unplanned events such as World War II pointed out some of the direction in which our schools needed to head. The well-developed engineering research establishment has to a great degree been propagated as a side benefit of the birth of some of the agencies. Of course, the development of federal support for higher education generally has represented a profound federal commitment to maintaining a national pool of well-trained individuals capable of advancing society. It has become a rather well-established principle, evidenced by such legislation as the Higher Education Act, that support of individuals and the facilities they use is a worthy endeavour. The study that you have undertaken represents a prime opportunity to review the success of that guiding principle in making the U.S. the world leader that it is.

What should the goals of a federal science and engineering policy be? What should the be the general goals? What, if any, should be the specific goals vis a vis engineering education?

First and foremost, I think, it is clear that the federal government has an obligation to consider the broad national interests in economic and military security when formulating policy. Federal science and engineering policy has obvious implications for both arenas. Therefore, in the broadest sense, a fundamental goal of such a policy should be the assurance of an adequate resource base for our science and engineering enterprises. How to attain this goal is the question that is before this Task Force.

I believe strongly that an important first step in developing a future science and engineering policy for this country is a thorough review of what has gone before. I won't attempt to comment in detail on the specific programs and policies that have existed or are in place today. I know that you have requested a complete history of these from other, far more authoritative sources. I would observe, however, that part of that history and a critical part of future federal action should be an ongoing analysis of the support mechanisms put into effect. Only then can we really grasp what impact federal programs have.

Also, I think that it should be a fundamental theme of federal science and engineering policy to distinguish among three major categories of support needs: 1) needs that are ONGOING, that will always exist; 2) solvable problems which require PERIODIC attention; and 3) concerns that require SPECIAL TARGETING of support. Being able to match an appropriate form of support to a particular need is not only an efficient use of limited funds, but vital to addressing a problem in the first place. For example, there will always be, I believe, a need to support young faculty attempting to establish themselves in the research arena. A program such as the Presidential Young Investigators Awards or the recently discontinued Research Initiation Grants program at NSF are fine examples of support which fulfills this need. An example of a 'solvable problem' may be the facilities crunch that your recently introduced H.R.2823 addresses. We don't need a major building campaign on a continual basis. A push on a periodic basis combined with a 'maintenance' program may be the most efficient answer to the problem. The recently established Engineering Research Centers at the NSF represent to me an example of special targeting of support to encourage, nurture and otherwise nudge advances in certain areas that are of clear interest to the nation. In the case of the ERC's, interdisciplinary efforts and manufacturing will get special attention. While these three general categories of support are not sacrosanct in my mind, I would encourage you to give some thought to dividing current programs and perceived needs into these 'piles' and analyzing how we fare in matching support to need.

I also have in mind some specific federal 'goals' with respect to engineering education itself. As with the three general categories of problems/support listed above, I've divided federal goals regarding our engineering schools into five general areas: QUALITY, FLEXIBILITY, CONTINUITY, PLURALITY, and EXPERIMENTATION. In several cases these terms apply both to the problem being addressed and to the shape of the federal policy itself.

QUALITY. The central importance of a highly-qualified engineering workforce to the economic well-being of the nation is well-established. I can't emphasize enough, therefore, the importance to the nation of providing our students and faculty with a quality environment in which to learn and work. If we shortchange either group we will pay on a large scale in the future by producing poorly-prepared engineers and out-of-date, frustrated faculty who can't carry on the fundamental engineering research that sustains U.S. technology.

Federal support of engineering education should reward and sustain quality in learning, teaching, and research. Programs to support people and to provide them with the tools they need should be first-rate; anything less will only cost more in the long run when we scramble to repair our mistakes.

Also, as I mentioned earlier, a thorough and ongoing analysis of the effect achieved by federal programs -- a kind of 'quality-control' -- should be fundamental to the support process.

FLEXIBILITY. Flexibility, I believe, will be the key to U.S. technological success in the future. In the marvelously free society in which we work and live, it remains next to impossible to assess our future manpower needs. And I'm not sure we should spend much time trying to do so. Instead, I think we need to concentrate on learning to be adaptable and on instilling an appreciation of life-long learning in the national psyche. Continuing education, I firmly believe, will be the most important educational, and perhaps economic, issue we face as the turn of the century approaches. We simply must have an adaptable and technically-current workforce to remain competitive in the world.

U.S. science and engineering depend not only on a strong core of particularly well-trained people, but also on the quantity of people who are capable of innovation and implementation. We must concern ourselves not so much with the growing diversity of fields (although interdisciplinary work is of increasing importance in engineering), but with the PACE of that change. We must prepare our graduates and our general workforce to cope with that rate of change.

Federal support should also recognize the need for our workforce to remain flexible in light of changing technology. Incorporating into the federal structure programs which acknowledge the increasing importance of continuing education would provide direct support of this emerging, critical area AND set the tone for activities in industry and on the state and local levels.

Ensuring that the SHAPE of federal support itself allows flexibility generally for engineering schools to respond to shifting technological and other needs should also be an important consideration. Schools, as well as their graduates, must be able to adapt in their own unique ways to special circumstances. They are in a favored position to decide on the need for resources to effectively solve their particular problems. Federal programs that permit a range of activities by schools should be in place to respond to these needs.

CONTINUITY. It cannot be reiterated too often that the educational process is just that -- a process. The gradeschoolers of today will be the scientists and engineers of a not too far distant tomorrow. Ensuring that this educational 'pipeline' is sturdy, of high quality, and open to the flow of talent is of prime importance to the health of U.S. science and engineering, and by extension, to U.S. competitiveness.

The preoccupation of the schools and government which support the pipeline has been very often with the big 'one-time fix' solution. While this haphazard approach has not yet grossly failed us, neither has it lent itself to efficiency or, sometimes, to fairness. For example, the need for new facilities has become such a pressing concern that some schools have circumvented the support mechanisms in place to have special provisions made for them. This is probably not the most effective approach to the facilities problem, nor to other support problems generally.

Providing continuity, I believe, is an important characteristic of good federal support. Protecting good science and engineering from the chaotic winds of political change is a valuable service and should be a fundamental element of federal science and engineering policy. Without a strong, continuous level of general support for quality people and quality tools we will continue to spend our time running to plug one hole after another in the pipeline. One example I can readily cite is the precipitous drop in graduate fellowships to a fraction of their level in only a little more than a decade. We'll have to scramble now to play catch-up over the next several years to make up for the resulting drop in the Ph.D. pool from which we draw our faculty.

Another observation I would offer has to do with providing continuity in projects in which the federal government plays an early active role and subsequently withdraws. An example might be the Centers of Excellence which figured so importantly in the 1960's. Before embarking on partnership-type or seedling enterprises, every effort should be made to insure that future support from other quarters will be available to sustain the effort. Otherwise, a great deal of money and effort can quickly go down the drain. On that note I am pleased to see that the National Science Foundation's ERC program contains a strong element of review and analysis.

PLURALITY. Another critical characteristic of good federal support is diversity. We should not be duped into believing that trying to develop a cohesive and long-term policy precludes approaching problems from a variety of angles. Different forms of support are important because each takes into account different viewpoints and different needs. Plural support mechanisms allow a mix of mission-oriented work and broader-ranging concerns. A balance of targeted and "unsolicited proposal" type support is a sound approach to funding. And diversity also reflects the fundamental strength of our own social and political systems.

I would make special note of the need to assess accurately the impact that mission agency research has on the educational process. A full understanding of how such research can affect the educational process will help in the development of other non-mission support to balance it.

As for the current diversity of support mechanisms -- each serves an important purpose. Fellowships support individuals; block grants allow institutions flexibility; project grants provide individual assistance while advancing research; traineeships target certain areas of need. Harking back to my earlier 'three categories' approach, a careful assessment of what types of problems each of these support mechanisms, and others, address might be warranted.

EXPERIMENTATION. Improvements in education -- as perhaps in anything -- come not just by dollars but by nurturing and experimentation. Money and creative ideas can be partners. The federal government can play an invaluable role in supporting and conducting innovative experiments in engineering education.

First, I should make clear that engineering education has changed substantially since World War II. From narrow, hands-on training to a broader, more theoretical program, engineering education's emphasis has shifted to the mastery of the fundamental engineering sciences and thorough grounding in problem-solving methods which allow application of these fundamentals to a broad range of problems. This emphasis is unlikely to change: in fact, as more specialists are needed to tackle new fields and interdisciplinary work, an even more broadly-based program which teaches adaptability will become key. What is more prone to change is the delivery system -- in the traditional classroom and in non-traditional continuing education settings.

For example, the standard engineering curriculum has been under stress for some time and and the strain will probably only grow. There are pressures to produce technically 'deep' people who are also well-rounded enough to interact in leadership roles in society. As much as we might like to, we can't teach it all in the four years given to us. And we certainly can't begin to add to the curriculum the explosion of knowledge happening all around us. What we DO do, however, is try to balance depth with breadth to produce a B.S. who knows how to approach almost any problem.

Educational technology will become increasingly important. Already such experiments as the National Technological University, which delivers Masters level engineering education via satellite to locations across the country, are revolutionizing the school system. More experimentation in this area is needed. The federal government can play an important catalyst and clearinghouse role.

Experimentation with curricula and with creative delivery systems deserves far greater attention, reward and support than it does receives currently. The National Science Foundation could prove pivotal in lending support and prestige to efforts to improve the teaching process. An important example currently in the works is a proposal by Dr. Nam Suh, head of the Engineering Directorate at NSF, to experiment with industry/academe team teaching. Dissemination of the results of successful small experiments in such teaching methods could spark major improvements in the teaching process. A similarly innovative idea was discussed at a meeting of engineering educators with Dr. George Keyworth, the President's Science Advisor, a year ago. A suggestion was made that serious experiments with changing the basic structure of engineering education be given the blessing of the federal government, to bring the attention and prestige necessary for schools to try risky innovations.

A whole series of experiment-type recommendations emanated from an ASEE/NSF workshop held in May on "Enriching the Undergraduate Experience". A great deal of attention was given to how non-research-oriented schools, designated Primarily Undergraduate Institutions (PUI's), could creatively work 'real-life' engineering practice into their curricula. Pointing out again that 50% of the country's B.S. degrees are produced at these PUI's where only 5.5% of NSF's engineering budget is directed, I encourage a close look at how the National Science Foundation and other federal entities can lend a supporting hand to the efforts of these schools to provide an innovative environment for their students.

Before offering some specific ideas for federal support of engineering education that have been raised in the academic community, I'd like to respond to your query about what ASEE itself is doing to address the problems of engineering education. I'd like to describe in a bit more detail an ASEE endeavor which I mentioned very early on in my statement: the Quality of Engineering Education Project, otherwise known affectionately as QEEP. I have included in the appendix to this testimony a more detailed summary of the progress of this study, but I'd like to provide you with some highlights now.

QEEP is a two-year study, the timeframe of which runs roughly parallel to that of your own science policy study. The Project grew out of the Engineering College Faculty Shortage Project that I discussed in some detail earlier. In December, 1983, a meeting with representatives of many of the major employers of engineers which are industrial members of ASEE was convened to review a proposal for the Project. Discussions and recommendations led to the creation of four task forces under the QEEP banner, each to study in depth a particular issue:

Task Force on the Preparation for the Teaching of Engineering
Task Force on Continuing Professional Development of the Faculty
Task Force on the Use of Educational Technology
Task Force on the Undergraduate Instructional Laboratory

Each task force has roughly equal industrial and academic representation. The Project also has an Advisory Board consisting of one member from each of the 28 industrial sponsors of QEEP, plus seven academic members appointed by the ASEE President. This strong element of industrial sponsorship and participation is an important characteristic of QEEP and is one of the things that sets the Project apart from other similar studies.

QEEP also differs from other studies of engineering education because its focus is very specific. The four task force charges are clear and the expertise on each panel is particularly relevant and extensive. I urge you to peruse the background on the Project that I've included in the appendix to get a flavor for the people involved and the work they've done in the nine months since the task forces began to meet.

What's going to keep QEEP from ending up as a pretty report on a dusty shelf? Well, there are never any guarantees that a study will have the impact that its authors intend. But we hope, for one, that deep involvement of industry as a partner in the Project will keep interest high in that quarter. We also have scheduled a number of presentations about QEEP all over the nation this fall and winter at various ASEE and other professional society meetings. There we hope to distribute a preliminary report of the task forces with the goals of receiving additional input and building broad community "ownership" of the study. When the final report is issued in September, 1986, it will contain specific recommendations for all of the stakeholders in the engineering education system -- schools, professional societies, industry, and government -- and will be disseminated widely. Copies will clearly be placed in the hands of those in a position to implement the recommendations.

I'd like to end my testimony with a few examples and ideas for federal level action to support this country's engineering education system. Some you have heard before. Some, I think, are quite new. A number of them I report to you as ideas discussed at the ASEE/NSF workshop on "Enriching the

Undergraduate Experience" that I mentioned earlier. All of them, however, serve one or more important function -- 1) providing a national level network, 2) acting as a catalyst, 3) lending continuity, 4) rewarding effort through prestige. The key is matching the type of support to the problem.

Let me give a quick example of each. A national clearinghouse/network for disseminating information on successful, creative delivery systems and educational technology would prevent the wheel from being invented on every campus. Targeting of funding and matching grant programs can stimulate large-scale partnerships among industry/academe/government without draining the public coffers. A dependable level of fellowship funding can prevent ups and downs in our pool of technological talent and keep the educational 'pipeline' flowing. Lending national attention and honor to important endeavours such as teaching, curricular experiments, and graduate study might go a long way to raising standards and the level of activity in such areas.

Another important theme for federal support should be a federal capability to assess thoroughly the level of support of people as they move through the pipeline and into the professional academic system. Monitoring the appropriateness of fellowship levels and availability, research grants, and non-monetary rewards is important to assure that our pool of innovators and educators is not starved for support.

On that same theme I cannot overemphasize the importance of adequate fellowship support for our M.S. and Ph.D. candidates. We cannot afford to let the numbers of U.S. citizens pursuing advanced degrees and academic careers remain as low as it is today. Fellowships must be competitive to at least some degree with starting salaries in industry. It has been suggested that fellowships should be at a level of about 1/2 the available starting salary in industry to attract the best students into graduate study. Strong consideration should be given to Presidential-type fellowships for graduate students. Attention should also be given to the idea of 'partnership'-type fellowships funded jointly by academe/industry/government. Forgivable loans for graduate students who will teach for a minimum amount of time should definitely be investigated.

Regarding the problem of providing a quality research environment to keep faculty up-to-date and to expose students to 'real-life' practice: a major overhaul of our instructional laboratories is a must. Creative approaches to obtaining equipment need to be pursued aggressively. Far too much of our equipment is older than the students we're trying to teach. Your bill, Mr. Chairman, H.R. 2823, represents an extraordinarily important effort to get our research infrastructure back into shape. We need to look into solving these huge facilities and instrumentation problems from a variety of angles, involving the private sector as much as possible.

I reiterate my earlier concerns that our non-research institutions are being generally overlooked in federal support for engineering. These schools are producing half of our engineers yet garner only slightly more than 5% of the Engineering Directorate's budget at NSF. Perhaps these schools could propose ways in which they can 'piggyback' onto the NSF ERC's. Perhaps an NSF 'honors' lectureship could bring "hot-topic" researchers to PUI's to share their latest discoveries. A stipulation in the PYI program could bring an awardee to a PUI campus for a visit to lecture or teach. Support for released time for faculty at non-research institutuions to spend time on other campuses to become involved in current research would be an excellent method of assuring faculty currency. Support for mentor/mentee programs between research and non-research school faculty also would help keep PUI's tied into current work. An analysis of other areas in which these PUI's can be strengthened is clearly worthwhile.

The federal government itself needs to take a look at its own policy toward continuing education. It varies considerably across the agencies. A more uniform policy is needed. Also, current tax policy provisions such as Section 127 -- employee tuition assistance --are necessary and perhaps should be strengthened. Continuing education, I firmly believe, is going to be the key to keeping our national workforce in step with the rapid pace of technology.

Thought should be given, too, to other government policies that do not provide direct funding or support to science and engineering, but which clearly have impact in those areas. I'm thinking of tax policy, including the above-mentioned Section 127 and the R&D tax credit. Anti-trust laws, intellectual property policies, immigration policy should all be assessed to see where they can be strengthened in support of science and engineering.

In conclusion, I'd like once again to thank you for inviting me to participate in today's hearing on behalf of the American Society for Engineering Education. I heartily admire the Task Force's willingness to undertake a thoughtful review of what has gone before in this nation's science and engineering policy and to consider where we're headed. I hope that my comments have proved helpful to you and I would, of course, be delighted to answer any questions which you may care to pose.

Thank you very much.

Mr. **Boucher**. Thank you, Dr. Lear.

Dr. Challoner.

[A biographical sketch of Dr. Challoner follows:]

Dr. David Reynolds Challoner

David Reynolds Challoner was born January 31, 1935, and raised in Green Bay, Wisconsin. He graduated from Lawrence College in Appleton, Wisconsin Cum Laude in 1956. He received his M.D. Cum Laude from Harvard Medical School in 1961, having taken a year's leave of absence as a Research Fellow in the Department of Biochemistry at Cambridge University in England. His post-graduate training included an internship and residency in internal medicine at Columbia Presbyterian Hospital in New York City, a chief medical residency at the University of Washington in Seattle and research training as research associate at the National Heart Institute of the University of Washington. His first academic appointment in 1967 was at the Indiana University School of Medicine where he rose to the rank of Professor of Internal Medicine. He subsequently served as Dean and Professor of Medicine at the St. Louis University School of Medicine from 1975 to 1982 and currently holds the position of Vice President for Health Affairs and Chairman of the Board of Directors of the Shands Hospital, all at the University of Florida. Dr. Challoner's scientific career has included research in endocrinology and metabolism resulting in over thirty scientific publications. His clinical speciality is in internal medicine with a subspecialty interest in endocrinology. His honors have included election to Phi Beta Kappa and Alpha Omega Alpha, the national medical honorary, the American Society for Clinical Investigation, and the Association of American Physicians. He was awarded the Harvard Medical Alumni Award in 1961 and was the recipient of the American Medical Association's Dr. William Beaumont Award in 1982 for "outstanding contributions to the profession of medicine by a physician under the age of 50." He has held leadership positions in many national organizations including the Association of American Medical Colleges where he holds Distinguished Service Membership, the American Medical Association where he served as Chairman of the Section on Medical Schools, and the American Federation for Clinical Reserch which he served as President. He has been elected a member of the Institute of Medicine of the National Academy of Sciences where he serves on the Membership Committee and as a member of the NAS Committee on National Needs for Biomedical and Behavioral Research Personnel.

He was married to Jacklyn Anderson in 1958 and they have three children, David, Laura, and Britt.

STATEMENT OF DR. DAVID R. CHALLONER, VICE PRESIDENT FOR HEALTH AFFAIRS, UNIVERSITY OF FLORIDA, GAINESVILLE, FL, ON BEHALF OF THE ASSOCIATION OF AMERICAN MEDICAL COLLEGES

Dr. **Challoner**. Thank you, Mr. Chairman.

Today I am privileged to testify on behalf of the Association of American Medical Colleges. It is not an organization that testifies frequently before this committee, so I should tell you that the organization represents the Nation's 127 medical schools, 79 societies from the academic medical disciplines, and over 500 teaching hospitals here in the United States. The Association welcomes this opportunity to comment on the status of the Federal Government's programs for the support of research training in the biomedical and biobehavioral sciences and on the effectiveness of these programs in supplying sufficient personnel to meet the current and future research needs of the Nation. We have a statement which will be submitted for the record, and I would like to highlight a few points of that for the committee and its members.

My comments are directed toward research training in the biomedical sciences, and for two specific categories of researchers: the Ph.D.'s and the M.D. researchers. I will try to highlight the specific differences in both of these cases. For the Ph.D.'s, all of bioscience education basically is research training. For the M.D.'s, all physicians, of course, receive the usual clinical education to prepare for patient care. Then physician investigators must undertake additional research training above and beyond that for the preparation of medical care.

The appropriateness of a Federal investment in biomedical research has been continuously reaffirmed, on a bipartisan basis, for over 40 years. An investment, Federal investment, in training is necessary to ensure the proper numbers of well qualified scientists.

There is congressional oversight of the entire training effort, both the Federal sector and the non-Federal sector. There is a very significant non-Federal sector. This is done currently through the National Academy of Sciences' study on research personnel needs.

It takes a large-scale national effort in order to provide the qualified scientists, and this effort has increased over time. There are some very important reasons for this.

First, what we are calling the new biology—such things as molecular genetics and neurochemistry—all require extensive training, usually up to 10 years or more in length following the baccalaureate degree. For instance, Ph.D. biomedical scientists will have an average of 7 years of graduate school training and then an additional 2 or 3 years of postdoctoral training before they become independent investigators. M.D.'s, of course, have the 4 years of medical school, at least 3 years of residency training, and then an additional 3 years of research training, which is usually correlated with some sort of subspecialty medical-clinical training.

Research training support is available through that entire spectrum for the Ph.D.'s. However, for the M.D.'s, for the most part, Federal support, research training support, is only available for the specific research training period. This length of training sequence requires a very large-scale program to yield a small cadre of qualified investigators at the end of the pipeline. It is a long pipeline and there is a large capacity to it, but you get a relatively small annual output. The national academy estimates that there are some 60,000 Ph.D. predoctoral and 15,000 Ph.D. and M.D. postdoctorals in the biomedical sciences—these are not all federally supported; that is the total pipeline—and the system annually yields approximately 2,200 Ph.D.'s, 1,200 M.D.'s, and 150 combined M.D.-Ph.D. degree holders who are fully trained to be independent investigators.

This scale of a biomedical research training effort requires the Federal Government to play a major role. Current Federal support is primarily through the National Research Service Awards, institutional training grants, and individual fellowships given by both NIH and ADAMHA. The Association of American Medical Colleges believes that the primary focus of Federal investment in research training should be through the institutional training grants which are specifically intended for educational purposes.

The NRSA supports 10,000 full-time-equivalent trainees a year of that pool, 10 percent of the national support for Ph.D. candidates, 35 percent of the support for Ph.D. postdoctorals, and 45 percent for M.D. research postdoctorals. That is all the Federal support.

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The system of biomedical research training is successful. What are the reasons, besides the Federal investment, for this success to date?

NIH and ADAMHA have the autonomy, flexibility, and the will to meet the perceived shortages and can respond to shifting research frontiers. The system is committed to quality in both the trainees and the programs. The system selects the most highly motivated and talented students, and the individual trainees are allowed access to programs tailored to their specific needs, goals, and talents. It is a national system, with a dispersal of talent to facilitate the flow of information and to enhance scientific productivity.

The NAS Committee on National Needs for Biomedical and Behavioral Research Personnel has proven successful at gathering data, estimating manpower needs, and projecting future personnel needs for the country and for the Congress. This committee and NIH-ADAMHA are aware of one important issue: the decline in the number of physician investigators. There is a decreasing percentage of clinicians who are serving as principal investigators on research grants. There is a decline in M.D. postdoctorals as a proportion of the total of NRSA-supported trainees. Physician investigators serve as bridges to achieve a synthesis of new basic knowledge with its clinical application. They go from the laboratory bench to the bedside, uniquely trained. They also identify important needs and opportunities at the bedside which are turned into questions at the laboratory bench.

There are existing training programs for clinical investigators. These were identified, and augmented new initiatives were introduced to ensure that the programs were available at each stage of training of physician investigators. Once the program was clear, the NIH has studied mechanisms by which they can work on this problem.

Current programs are basically as follows. They begin with initiatives in encouraging research careers among medical students. There is NRSA short-term research training grant which provides summer research opportunities. The Howard Hughes Institute and the NIH, as you may have heard recently, sponsor medical students for a year in the NIH laboratories, medical students who are willing to take off a year for research training.

Next, the Medical Scientist Training Program provides in-depth training for individuals whose interests can be identified in college. This is a 6- to 7-year dual-degree M.D.-Ph.D. program. The success of these trainees in research is well documented. Since 1974, the number of institutions participating in this program has doubled.

NIH has further adapted the training grant mechanism, which extends the duration of the postdoctoral period, encourages greater depth and interdisciplinary approaches to physician research training, and provides a continuum of support from training grants to individual fellowships, all to facilitate the development of the physician investigator.

There is a new program, the Physician Scientist Award, which was initiated to attract more physicians to research careers. This program has duration and intensity training skills to provide clinically trained M.D.'s with basic research skills.

The effectiveness of this series of initiatives that I have described to you has not been hampered by inadequacies in the grant mechanisms or a lack of qualified applicants, but by a lack of available resources. The Medical Science Training Program has 25 training sites and 680 programs—that is the M.D.-Ph.D. program—but the system could accommodate more sites and trainees. The physician scientist program currently involves only 40 individuals, but a lack of funding prevents additional applicants.

There are significant disincentives to a career as a physician scientist, amongst which are—and increasingly so—the debt burden of medical school graduates, as various kinds of support programs for regular undergraduate medical school training have declined; and the NRSA payback provision for trainees unable to sustain a research or teaching career. They know they have to pay back year for year in some teaching or research environment for each year of Federal support they receive. For a physician to choose a research career, he is making a negative career economic investment. There also is certain uncertainty about stable grant support for meritorious investigators should one choose a research career, so that the decline in the number of physician investigators entering the system will gradually end up having an effect on medical school faculties as well.

That is of some concern, because the faculty currently in place are the product of the broad-based research training efforts in the sixties and seventies. Federal appropriations for research training have now decreased. The faculty in place are aging. A vigorous Federal commitment to research training must be considered to meet these anticipated needs in the system currently in place.

Those of us who are here this morning were asked about potential new strategies for our areas of expertise. The system for biomedical research training can create mechanisms to meet the particular needs of the different stages of research career development. I think that is an important message we can give your committee in its study. The mechanisms are fully capable of providing equality, breadth, and depth of training needed to respond to future research challenges. What is needed is sufficient and stable support to sustain—and, in some special programs, expand—our present training capabilities.

A critical policy question in the area of biomedical research training is how to allocate funding within increasingly constrained resources to take advantage of the system's current effectiveness.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Challoner follows:]

STATEMENT

OF THE

ASSOCIATION OF AMERICAN MEDICAL COLLEGES

"Research Training and Manpower in the Biomedical Sciences"

Presented to the
Task Force on Science Policy
Committee on Science and Technology
U.S. House of Representatives

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Thank you, Mr. Chairman.

I am David Challoner, and I am the vice president for health affairs at the University of Florida. Today I am testifying on behalf of the Association of American Medical Colleges, which represents the nation's 127 medical schools, 79 societies from the academic medical disciplines and over 500 teaching hospitals. The Association welcomes this opportunity to comment on the status of the federal government's programs for the support of research training in the biomedical and biobehavioral sciences and the effectiveness of these programs in supplying sufficient personnel to meet the current and future research needs of this nation.

Before I begin, I would like to point out that my comments this morning are directed toward research training for Ph.D.s and M.D.s. All Ph.D. education in the biosciences is research training. For M.D.s, it is important to distinguish between the clinical training that all physicians receive to prepare for careers in patient care, and the additional, specialized research training necessary for future physician investigators.

The federal government has continuously reaffirmed, on a bipartisan basis, its commitment to the support and conduct of biomedical research during the last 40 years as an important vehicle for achieving its goal of improving the health of all citizens. A fundamental and legitimate component of research support is the derivative responsibility to ensure that proper numbers of well qualified scientists will be available to continue the research effort. The Congress recognized the importance of overseeing the entire biomedical research manpower effort -- both federally and non-federally funded -- when it incorporated a continuing study of biomedical and biobehavioral research personnel needs, under the auspices of the National Academy of Sciences, as part of the National Research Act of 1974.

During the past decade, the national need for strong, stable programs of research training in the biomedical sciences has dramatically increased. The exponential expansion of the "new" biology in fields such as molecular genetics, neurochemistry, and immunology, requires a lengthy period of training, usually at least ten years after college. During this time the trainees acquire the type of in-depth, multidisciplinary education necessary to be productive, independent investigators and stay abreast of rapidly shifting research frontiers. For Ph.D.s, this means an average of seven years of graduate school followed by two to three years of postdoctoral research experience. For M.D.s, there are four years of medical school, at least three years of a clinical residency, and then a minimum of three additional years of research training correlated with subspecialty clinical training. Programs for research training support the M.D. only during the research training period, while such programs are available to the Ph.D. throughout the graduate school years. The length of this training sequence requires a large scale program which must sustain sufficient numbers of trainees at each stage to eventually yield a small cadre of well-trained independent investigators. The National Academy of Sciences estimates that nationally there are 60,000 Ph.D. predoctoral candidates and 15,000 Ph.D. and M.D. postdoctorals in training in the biomedical sciences. This system yields approximately 2,200 Ph.D.s, 1,200 M.D.s, and 150 M.D./Ph.D.s per year who have completed postdoctoral programs and are fully trained for careers as independent investigators.

The scale of this biomedical research training effort is of such magnitude that the federal government must play a major role in order to ensure enough properly trained scientists to assist NIH and ADAMHA in their mission of advancing knowledge and improving health. Some research training is provided when students participate as research assistants on federal research grants. Currently direct federal support for research education in the biomedical sciences is achieved through the National Research Service Awards (NRSA) program, which awards institutional training grants and individual research fellowships primarily through NIH and ADAMHA. The AAMC has long maintained that the primary focus of the federal investment should be through direct institutional training grants, which support both research training and the educational milieu. To sustain the research training effort, the NRSA supports over 10,000 full-time equivalent trainees per year, contributing 10 percent of the national resources for the support of Ph.D. candidates, 35 percent for Ph.D. postdoctorals, and 48 percent for M.D. research postdoctorals.

This highly evolved system for research training in the biomedical and biobehavioral sciences has produced individuals who have served the nation well. Their research achievements as career investigators have contributed greatly to improving health and curing disease over the last 40 years. Without this trained cadre of investigators, it is doubtful we would have made such strides.

There are a number of other key components beyond the federal investment that are responsible for the success of the research training system. The agencies responsible for biomedical research training, the NIH and ADAMHA, possess the autonomy, the flexibility, and the will to create appropriate mechanisms to meet perceived needs or shortages, and to respond to shifting research frontiers.

Another factor that has contributed to the success of this training effort is the deep commitment to quality embodied in the search for the best and brightest potential trainees, regardless of origins, and the best calibre of training sites. The importance of this emphasis on quality should not be underestimated. Training for scientific research is a demanding, rigorous pursuit, and success is best ensured by a system that selects the most highly motivated and talented students. At the same time, the system is designed to allow individual trainees access to the best educational programs tailored to their specific needs, goals, and talents. A range of different support mechanisms appropriate to the varying stages in the maturation of a scientist is available.

Yet another positive aspect of this country's system of biomedical research education is that it is national; M.D.s and Ph.D.s who successfully become independent scientific investigators are a national resource and after training pursue their careers in a wide range of institutions. This dispersal of talent is a major strength of the system because it facilitates the flow of information and enhances scientific creativity and productivity.

In the last decade judgments about the scope and scale of federal training commitments have been supported by the work of the National Academy of Science Committee on National Needs for Biomedical and Biobehavioral Research Personnel. The system employed by this committee has proven effective at gathering data, estimating manpower trends, and projecting future research personnel needs. The NAS provides an independent check on the system's ability to fulfill future research manpower needs and commissions studies of the effectiveness and productivity of specific programs. The committee chairman, Dr. Robert Hill, has already described the committee's perspective to you. Their recommendations regarding the federal role in the support of research training have earned the confidence and respect of the agencies -- NIH and ADAMHA -- and the Congress.

Over the last decade, the NAS Personnel Needs Committee and the NIH/ADAMHA became increasingly aware of a decline in the number of physician investigators to the point where they have been termed an "endangered species." There has been a decreasing percentage of clinicians serving as principal investigators on research grants and a decrease in M.D. postdoctorals as a proportion of the total NRSA supported research trainees. Physician investigators serve as vital bridges to achieve the necessary synthesis of new basic knowledge with its application to clinical problems. They also employ their clinical knowledge and experience to identify important needs and opportunities for basic research.

As a result of these concerns, existing programs which provided training support for clinicien investigators were identified and, where possible, augmented, and several new initiatives were introduced to insure that programs were available at each of the stages deemed critical in the training of a physician investigator.

Current programs begin with initiatives to stimulate interest in research careers among medical students. NRSA Short-Term Research Training Grants are awarded, which provide summer research opportunities to medical students to encourage research careers and establish mentor relationships. Recently the Howard Hughes Institute has joined with NIH to sponsor a program in which medical students may spend a year doing research at the NIH laboratories.

The Medical Scientist Training Program (MSTP) represents an opportunity to provide in-depth training for those students whose interest in a biomedical research career can be identified in college. In this program, the student completes both the M.D. and the Ph.D. degree in a six- to seven-year period. The success of these graduates in productive research careers is well documented, and since 1974 the number of institutions participating in this program has doubled.

In an effort to enhance the success of the physician investigator in the increasingly competitive, complex research environment, the NIH has further adapted the training grant mechanisms to extend the duration of the postdoctoral period and to encourage both greater depth and interdisciplinary approaches to physician research training. A sequence was recommended in which trainees could move from training grants to individual fellowships, thus providing a continuum of support as the individual moves toward more advanced and independent research.

Recently the Physician Scientist Award was initiated to help attract more physicians to research careers. It provides a training sequence of the intensity and duration now deemed necessary to provide a clinically trained M.D. with the basic research skills needed for modern investigation. These awards begin after residency training, and provide a stipend and a significant investment in the training milieu of the young physician for five years. In the first 2-3 years each trainee receives a sophisticated education in basic science research, which he then learns to apply to problems in clinical research.

Efforts are also being made to increase the participation of physician investigators in the NIH Research Career Development Awards program. This series of grants has long been utilized to provide support during the critical transition period to independent status as an established investigator, but the percentage of physician scientists receiving these awards has declined in recent years.

The effectiveness of each of these initiatives has not been hampered by inadequacies in the grant mechanisms or a lack of qualified applicants. Instead it has been a lack of available resources that has limited the growth of each program. For example, the MSTP program currently has 25 training sites with a total of 680 individual participants, but the system could easily accommodate more trainees and additional sites with no decrease in quality. The Physician Scientist Program currently involves only 40 individuals, but a lack of funding has already prevented some individual institutes from considering additional applicants.

Disincentives to students considering a career as a physician scientist which have been identified but which have yet not been amenable to remedy include the increasing debt burden of medical school graduates, the provision requiring payback of the NRSA stipend should a trainee later be unable to sustain a research or teaching career, and the present climate of uncertainty about stable research grant support for meritorious investigators.

A decline in the number of successful physician investigators entering the system will gradually have a significant effect on the faculty ranks in our nation's medical schools. Many of the research faculty now in place are a product of a broad-based research training effort in the 1960s and early 1970s, before federal appropriations for research training decreased to their present levels. These faculty are aging and a vigorous commitment to the federal role in research training must be continued to meet these anticipated needs.

The participants on this panel were asked to comment on new strategies for improving our education system. The nation's system for biomedical and biobehavioral research training has shown the ability to create a spectrum of appropriate and heterogeneous mechanisms to meet the particular needs of the different stages of research career development. These mechanisms are fully capable of providing the quality, breadth, and depth of training needed to respond to future research challenges in the biomedical sciences. I would like to submit that what is needed now in the biomedical sciences are not new or improved strategies, but rather sufficient and stable support to sustain and, in some programs, expand our present training capabilities.

The critical policy question that faces the federal government in the area of bioscience research training is not how to make the system more efficient, but rather how to allocate funding within increasingly constrained resources to take advantage of the system's effectiveness.

Mr. **Boucher**. Thank you, Dr. Challoner.
Mr. Weinert.

STATEMENT OF DONALD G. WEINERT, EXECUTIVE DIRECTOR, NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, ALEXANDRIA, VA

Mr. **Weinert**. Thank you, Mr. Chairman.

I welcome this opportunity to bring the views of the 75,000 members of the National Society of Professional Engineers to these hearings. Our membership represents engineers of all disciplines, all areas of practice—industry, education, construction, private practice, government—and, as was mentioned earlier, a substantial number of engineers are employed directly by government—6 percent—and, as Ed pointed out, up to 30 percent if you consider the indirect.

We would like to present through my statement a series of factors that we think you should give careful consideration, both as you review policy and analyze policy formulation and as you develop new strategies.

There have been a lot of changes since Vannevar Bush put out his report in 1945, explosions of technology, a completely different world in which U.S. technological preeminence is not only no longer a fact; it is seriously challenged across the board in many areas. It is time, and we compliment you, for undertaking this review.

The first point I would like to make involves distinctions. There is a distinction been science and engineering. They are certainly closely related and complementary. In the draft remarks that I had passed out before this hearing, you will notice that "complimentary" is spelled with an "I." It was intended to be spelled with an "E." However, both apply in the relationship between science and engineering.

The reason I bring this point out, and why I think it is important for your consideration, is that in reviewing and looking at policy, those distinctions—and there are several—should be kept in mind. Policy differences may be required to deal with the special needs of engineering as it relates to science.

Data collection, for instance, interestingly enough, tends to lump science and engineering personnel into one big pot. That can be very deceiving. If we were to undertake a massive rehabilitation of our infrastructure in the United States—highways, bridges, roads, dams, sewer systems—we would need lots and lots of civil engineers. There probably would not be much reflection in any increased numbers, or need for scientists, or any of the other engineering disciplines. It is very important that we be more discrete in the way we represent the numbers and types of scientists and engineers in the United States.

The next point I would like to make has to do with the subject of these hearings, supply and demand. When people talk about supply and demand, they typically think numbers, and I would caution the task force against focusing on numbers. It is true that the market is a very strong determinant of the numbers and, to a great extent, the types of engineers and scientists that are needed.

Government does not have an unusually good record in interfering with market forces or governing market forces. I think, rather, the focus—to emphasize something Dr. Yankwich said—should be on quality, that component of supply and demand. We want to make sure that we have the best engineers and scientists and that they are utilized properly and that we are developing our technological knowledge base properly. There is a role for Government. To try to manipulate numbers, I think, would be very futile. So I would urge, in the supply-demand consideration, that you consider the quality of that supply and what government can do to ensure that quality rather than worry about the numbers of electrical engineers or petroleum engineers or a particular type of scientist.

If you look at the unemployment figures for engineers in the United States over a long period of time—go back 30 years—you will note that the unemployment rate is consistently 2 to 3 percent; it is a fairly steady employment. And the demand curves—and there is one attached to my statement—all are going up.

The market seems to be dealing, notwithstanding momentary dislocations, spot shortages, disruptions when technology shifts dramatically, notwithstanding those changes, the supply and demand driven by market forces tend to balance pretty well over the long haul.

The next point I would like to make deals with one of the differences between science and engineering. While it is true that many engineers go on to get a master's degree or a Ph.D. and do graduate work, it is also true that the basic entry-level degree for practicing engineers in this country is a bachelor of science degree, and institutions focused on producing large numbers of bachelor-degree engineering graduates have, to some extent, not been able to bask in the light of Federal interest and attention as far as funding resources. Those have tended to focus on Ph.D.-producing institutions, focused largely in research-based institutions.

There is and has been a real danger of a bimodal system developing, particularly as it relates to the production of engineering graduates. We will continue to need more and more engineers with advanced degrees, while I think it is also clear that we will continue to have a large number of practicing engineers come out of bachelor's programs, and we need to pay attention to those schools and to give them as much Federal interest as we have been able to give the research-based institutions up until this time.

As an example, if you look at many of those schools that are focused primarily on bachelor-level engineers, you will notice the condition of their labs is deplorable. Their laboratory facilities and equipment have not benefited from large infusions of capital. Even though industry has been quite helpful and generous, they have fallen far short of the need.

Another point I would like to call to your attention has to do with the quality of new hires. It is a subject I know you all have heard a lot about. You go around and talk to large employers of engineers and they tell you that these are the best engineers we've ever gotten.

Well, of course, they are good. They rank generally in the top 10 percent of the undergraduate population in any college—and, incidentally, that is not a new phenomenon; that has been going on for some time. Schools with declining resources, in order to balance their resources and their incoming students, have had to further restrict entrance requirements, so that has raised the level a little higher.

Certainly the engineers coming out are good. That is not the question. The question is how much better could they be if our educational system were even stronger and if some of the problems that Dr. Lear points out are dealt with effectively. It is the value added that is important.

With 45, 50, and—in the case of one of my sons who recently graduated from an engineering school—80 people in a class, there is no opportunity for interface with the professor. In sensitive design courses and developing those design skills where interchange is important, it is not really possible to get it. And I have mentioned the lab problem.

You talk to a large employer who gets a new hire that is obviously bright, and frequently the managers have been out of school for 20 or 30 years, and they don't know a lot about computers, many of them, and these kids are really great with computers; there is a halo effect there. When you see one of these kids that knows so much about computers, you tend to think he is really brilliant. Well, he just happens to know some things you didn't know as well because you weren't supposed to. So I caution you, on the quality of new-hire business, to conclude that everything must be great. They are good, but they could be a great deal better, and I think the industry leaders and the academic leaders agree on that point.

Another point I would like to make has to do with expanding our technological base, our knowledge base. We have many good programs now developing centers of excellence around the country. DOD has a program that is about to take off; the National Science Foundation has an excellent program; IBM and other large industries have started their own programs; and the response has been overwhelming. The universities are eager to participate in these university-based centers of excellence, and there is a plethora of proposals flowing in from all sources. Somebody has to help sort that out, and I call that to your attention. I think there is a role for the Federal Government here. I don't know whether it is OSTP, whether it is National Science Foundation, whether it is something else, but we have got to have some way to help sort out all of the proposals that are flowing in for all of these various initiatives to help expand our technological data base and knowledge base.

A final point on the Federal engineers that I wanted to make has not to do so much with numbers as it has to do with compensation. David Packard chaired a group, a White House Science Council study on Federal labs, and made some recommendations about compensation of scientists and engineers in the Federal Government, particularly in the labs. They must be competitive in their compensation system if we are going to have top quality working for the Government, and I urge you to give that some thought and to look at those recommendations carefully.

In conclusion, I would just like to come back to the beginning. As you get into this, I urge you not to become preoccupied with numbers, whether there are shortages or surpluses of scientists and/or engineers in any given area. Focus, again, as Dr. Yankwich said, on quality.

Thank you very much.

[The prepared statement of Mr. Weinert follows:]

NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

NSPE

TESTIMONY
OF
DONALD G. WEINERT, P.E.
ON BEHALF OF THE
NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS
ON THE
SUPPLY AND DEMAND OF SCIENTISTS AND ENGINEERS
AND THE
QUALITY OF ENGINEERING EDUCATION

SCIENCE POLICY TASK FORCE
COMMITTEE ON SCIENCE AND TECHNOLOGY
JULY 23, 1985

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Chairman Fuqua and Members of the Task Force:

Thank you for the invitation to appear before you to discuss the supply and demand of scientists and engineers, and the quality of engineering education. I am Donald G. Weinert, P.E., Executive Director of the National Society of Professional Engineers (NSPE). Prior to assuming my current position, I served 26 years with the US Army Corps of Engineers, where I had extensive exposure to engineering supply and demand issues, both in the federal government and in the private sector providing government services.

NSPE is a professional engineering society, representing over 75,000 engineers of all disciplines nationwide. Our members are organized into 50 state societies and 500 local chapters, and work in industry, education, private practice, government, and construction.

We are most encouraged by the serious, comprehensive examination of Federal science and engineering policy being conducted by this Task Force. Many of the policies which govern Federal investments in science and engineering research and education were enacted over two decades ago, when American preeminence in technology was unquestioned. Since that time, we have entered into an era where competition for technology markets is global rather than domestic, and where Federal expenditures are scrutinized more carefully than ever before. It is therefore an appropriate time to examine our Federal science and engineering policies to ensure that we are maximizing the government's ability to foster appropriate research and education activities, and to determine if changes are necessary to adjust to new economic and technological circumstances.

Since the Vaneveer Bush Report was released in 1945, the engineering profession has changed dramatically. Advancements such as the invention of the transistor in 1948 and the genetic engineering techniques that are currently being developed have led to a diversification of engineering practice. While the line between fundamental engineering research and pure scientific research is often fuzzy, distinctions should be made between engineering and science in many policy areas. This is particularly important in terms of supply and demand data, where the Federal government now lumps all scientists and engineers together in one S/E category. Science and engineering personnel are not interchangeable, and a shortage or surplus in one of these areas does not imply the same in the other. For example, if a major effort to repair American public highways and other infrastructure needs were launched, demand for civil engineers would see an increase, without any likely impact on demand for scientists. To include both engineers and scientists in one data set can be very misleading, and can foster the misconception that they are the same field of endeavor. Science and engineering are complementary to be sure, but they are distinct in character and should be viewed as such when developing public policy.

NSPE understands the concern of the Task Force about U.S. scientific and engineering manpower needs. However, we believe that supply and demand of engineers are governed by market forces which respond to overall economic activity as well as to Federal science and engineering policy priorities. Supply and demand data may reflect government policy, but they should not dictate that policy.

We point out that even in the most deep recessions, demand for overall engineering employment remains high, with unemployment rarely rising above 3%. Figure 1 on the attached page illustrates this point. Fluctuations exist both between disciplines and geographical areas, but because there is currently a need for more electrical engineers one cannot conclude that there is a shortage of engineers in general. In fact, at the same time that demand for computer specialists is high, there is an oversupply of petroleum engineers. If you accept [illegible] ~~the premise that given~~ the rapid pace of technological change and the increasing penetration of technology into all aspects of society, then it becomes clear that the promising picture of engineering employment will grow even brighter in future years. Consequently, NSPE believes that Federal policies should be aimed not at producing more engineers, but at ensuring the highest quality of engineering education and the expansion and application of technological knowledge.

We urge the Task Force to examine these issues of quality by focucing on the environment of engineering research and education and the utilization of engineering resources. I know you have already heard testimony on the quality of engineering education from several excellent sources, and since I am confident that Dr. Reyes-Guerra from the Accreditation Board for Engineering and Technology (ABET) will further illuminate these issues tommorrow, I will focus my comments on three related areas.

First, Federal policies have historically focused on PhD level research as the most effective and appropriate means to foster excellence in science. Since most top-level scientific research is conducted at that level, and, since the PhD is considered necessary to achieve distinction in scientific fields, this policy trend seems appropriate. However, the situation in engineering is quite different. Unlike science, the entry level degree for engineering practice is generally considered to be the B.S., not the PhD. (see figure 2) Approximately half the nation's B.S. graduates are granted by colleges of engineering that are substantially oriented toward undergraduate instruction. Because Federal investment has concentrated on graduate level engineering research and education, these schools have not benefited from government programs and have not always been able to keep pace with those more focused on PhD production.

While not every engineering college needs to have cutting-edge laboratories, the current condition of labs in the majority of engineering schools is deplorable. Although current efforts on the part of industry and state governments are helping, Federal activity has again mainly benefited the prestigious research universities. It is these same schools which are best able to attract industry support, leaving many outstanding institutions dedicated to undergraduate education with deteriorating resources and limited external sources of funding. There is a danger of a bimodal system of engineering education developing in our country. Immediate attention should be given to undergraduate instructional needs for engineering. We urge the Task Force to carefully consider this problem and explore solutions.

Second, I would like to address the apparent conflict between the reported severity of engineering education problems and industry satisfaction with recent engineering graduate hires. There is no question that our engineering schools are graduating top-quality students. However, to put the issue in perspective one must look at the quality of students entering engineering schools. Compared with students throughout all the colleges within a given university, engineering students rank in the top ten percent. And given the popularity of engineering programs, schools are further tightening admissions in order to balance their resources. The question, then, is not whether or not quality students are being graduated, but whether the incremental value added by the educational process is as high as it could be.

Leaders in BOTH academe and industry are clearly concerned that we are not getting the most out of the educational process. With classrooms of 45 students or more, personal contact and individual instruction is minimal. The ability of instructors to provide close guidance during design courses which require constant interchange is extremely limited. We are convinced that with more modern equipment, better facilities and lower student/faculty ratios, the quality of engineering students could be greatly enhanced.

Another consideration in the quality issue is that large, prominent companies are skimming off the top students, and have the resources to provide any necessary additional training. Smaller companies are more limited in their ability to further educate and train graduates. From these companies, we hear of needs for better communication skills, ability to work on team projects, and knowledge of quality control methods. Another point frequently raised is that there is an assumption that because a student has sophisticated computer skills, they are well trained in general. To managers who lack computer knowledge of a 22-year old graduate, these skills imply overall brilliance which may or may not actually be present.

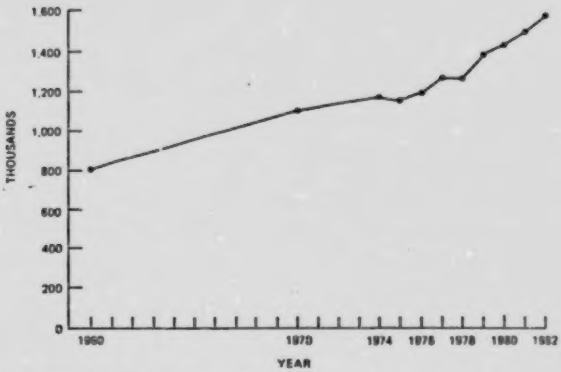
Third, I would like to comment on current efforts to redress problems of quality in the education process and development of our technological knowledge base. Several excellent programs are either in place or being established to develop university-based centers of excellence in a given research area. Among the programs I am referring to are NSF's Engineering Research Center Program and the newly proposed DOD University Research Initiative. These programs both leverage private sector support and reach out to all types of engineering schools. As a result, the proposal response has been overwhelming. Not only are the funding agencies being flooded with proposals, but companies are being deluged with requests for matching funds. It would be helpful if the Office of Science and Technology Policy (OSTP) could provide a coordination of these programs so that industry can be aided in their efforts to sort out requests for support. The private sector has and will continue to respond favorably to matching grant programs; however, assistance is needed to better understand and differentiate among the various programs for which funding is being sought by universities.

Finally, I would like to call your attention to the issue of Federal employment of scientists and engineers. As a Panel member of the recently completed National Research Council Committee on the Education and Utilization of the Engineer, I was surprised to learn that the government directly employs six percent of all engineers. When indirect employment is taken into account, that figure rises to 30%. Given the dependence of the government on engineering talent, the Federal government should examine and improve compensation policies for scientists and engineers. The relevance of this issue to the ability of Federal laboratories to recruit and retain top-flight researchers should be of interest to this Task Force. With salaries significantly below those offered by the private sector, it should be no surprise that Federal labs have difficulty attracting the nation's top scientists and engineers. The White House Science Council's Federal Laboratory Review Panel, chaired by David Packard, closely examined this question. I am aware that a proposal for a new and better compensation system for scientists and engineers was drafted in response, which has been circulating through the Administration for many, many months. We recommend that the Task Force look into this issue and seek action with regard to the Packard recommendations.

In conclusion, NSPE endorses your study of U.S. science and engineering policy, and have tried to outline several areas for your attention. We caution against a preoccupation with manpower supply and demand issues since we strongly believe supply and demand of engineers is governed by market forces far more than it is by federal policy. We urge you to focus on quality of engineers and their utilization rather than quantity.

Thank you very much for the opportunity to share our views with the Task Force. We are pleased to further assist you as your work continues.

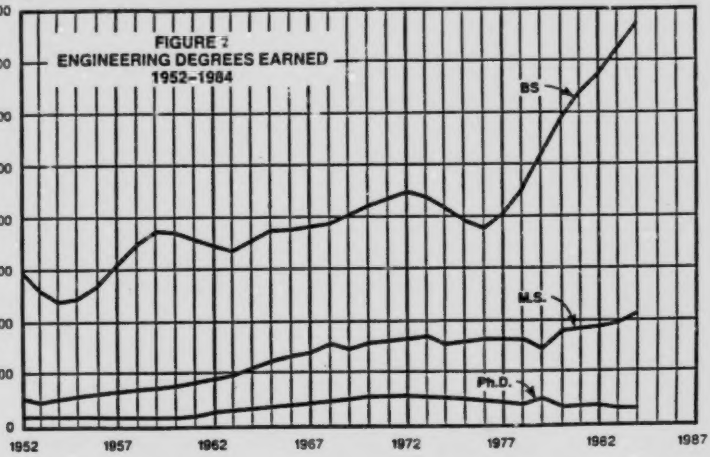
FIGURE 1



EMPLOYED ENGINEERING PERSONNEL, 1960-1982.

Source: Report of the Panel on Engineering Employment Characteristics

FIGURE 2



EMC, Engineering Manpower Bulletin, December 1984.

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PANEL DISCUSSION

Mr. **Boucher**. Thank you, Mr. Weinert.

The questions that I will propound, I will propound to the entire panel, which, by the way, we thank very much for the thoughtful presentations made this morning.

Please do not observe any particular order in responding to the questions. In fact, I would appreciate hearing a response from each of the four witnesses if they care to respond to the specific questions.

I gather that one of the primary problems that we have with regard to engineering faculty today is the fact that there is such a tremendous demand for bachelor-level engineers in the private sector that they are being enticed away from the campuses by the lure of high salaries and are not pursuing graduate degrees. That in turn restricts the number of faculty available, and that in turn can have a long-term adverse effect on the number of engineering graduates overall. Is that problem also present in the fields of the sciences, or is that restricted just to engineering?

Dr. **Yankwich**. The principal difference between faculty qualifications in science and engineering is the doctorate. Up until the late thirties, even major engineering schools had relatively few faculty members who held doctorates. At the same time, in most research universities, the doctorate had been the norm as the entry level for faculty positions for 30 to 40 years in all of the hard sciences.

In the period that started just before World War II and ended in the sixties, there was a very rapid conversion in research universities to doctoral-based faculties in engineering, and now the smaller engineering schools are following suit as they are able.

The problem, which is very critical in some areas of engineering today, was never faced under the pressures of economic expansion by the hard sciences. It is peculiar to engineering, and it is a result of the shift to a higher level of qualification being rather suddenly demanded in terms of numbers of faculty.

Mr. **Boucher**. Thank you very much. Would anyone else care to comment on that?

Dr. Lear.

Dr. **Lear**. Let me just expand a little on the comments that Dr. Yankwich has made, and they are certainly correct.

Following World War II, there was a very dramatic change, not only in the move toward graduate study and research in the engineering colleges of the Nation, but a basic change in the undergraduate programs, which caused them to lean much more heavily on a science and mathematics base to give the student a kit of tools which allowed him to swing with technology more easily. But that is an aside.

The basic point that you asked about, having to do with the shortages of faculty and the shortage of a pool of people coming through the doctoral stream, is a result of the fact that the engineering colleges, over the past 25 or 30 years, have moved to a stance where the bulk of the faculty in most institutions is one which has the doctorate as the base degree.

You might ask the question whether that is an appropriate thing for the engineering colleges today. I think it is certainly more appropriate than it was in the time that Dr. Yankwich mentioned as a starting point, but the basic issue is how much do we need in the way of the doctoral level type of training for engineering faculty as opposed to comparable experience, for example, in industry.

It is a difficult question to answer, and it is one that one of our task forces that I mentioned in my remarks is addressing very seriously: What is an appropriate balance in an engineering faculty of doctoral-level people and ones who may have experience which is not the doctorate but something which is surely comparable in terms of the needs of the teaching establishment?

I think that we are going to come out on the side of concluding that the great bulk of the faculty in the engineering schools where there is a graduate program and where there is research going on should have training at the depth of the doctorate because they are going to be training other people who are in graduate programs and certainly need to have that kind of understanding.

But not all engineering professors need to have doctorates, and what kind of balance we need to come up with is certainly a question that we need to decide. But in the current climate, whether that balance is 80 to 20 or 90 to 10, whatever it is, the pool out there is so small that we are in deep trouble regardless of which way we lean on that score.

Mr. BOUCHER. I gather that your conclusion will be that a substantial pool of doctorate-level faculty will be necessary in order to maintain quality in engineering programs. That being the case, I guess it is fairly obvious that one way to ensure that you have doctorates graduating from our universities today is to expand the number of faculty members to make sure that there are spaces available and that faculty is available to teach. Don't we have to worry about numbers? I noticed Mr. Weinert was saying quality is really the issue. But in faculty positions today, don't we have to worry about numbers?

Dr. LEAR. Well, certainly. We can't get away from the fact that we are talking about faculty positions. I like to use a combination term, "adequate numbers of qualified people," and that gets you around both of those considerations, of course. But we have talked in terms of numbers in documenting our faculty shortage. We talk about 8 to 10 percent of the budgeted faculty positions being open. We talk about how many we should have in order to provide a quality education beyond that budgeted number, and it is a much larger number. But I think the issue that Mr. Weinert raised is an important one. It is not just the numbers; it is the quality of that system.

I recently did a little study for some work last week that the National Academy of Engineering was doing with a group of deans of engineering to look at the supply-demand picture in terms of the graduate student numbers that were coming out in the future, and we have an increase in the number of people going on to graduate school now over the last 2 or 3 years, so, all things working out as they should, we will have an increase in the next 3 or 4 years of the number of people coming out of the system, and we can make pretty good predictions about that number.

But that number does not tell us anything about quality. Certainly we are going to have more people available. The number turns out, incidentally, still not to be enough to fill the slots and to take up the slack for the normal attrition in the system.

But what has happened is that the brightest and best have not been going on to graduate school in recent times, and we need to turn that around. So we are not dealing just with numbers. We need to take the quality issue into account.

Mr. **Boucher**. It seems to me that if we are going to encourage undergraduate engineering students to consider obtaining advanced degrees, there is going to have to be an increase in compensation for people in teaching positions. That is the only incentive I can imagine that is going to be very meaningful to a young person trying to decide whether to go into the private sector or whether to pursue an advanced degree and become an educator. And what is the Federal role as you would see it—and I would ask the entire panel to comment—if indeed there is a Federal role at all, in ensuring that salaries for faculty members are adequate to provide that level of incentive?

Dr. **Lear**. I personally see that as a job for the institutions themselves to ensure that the salary levels are adequate. That is not the whole incentive picture, though. Salary is not the only thing; it is the working environment. I think there the Federal Government does have some place to——

Mr. **Boucher**. Could you elaborate on that?

Dr. **Lear**. Well, I am thinking specifically of things like the laboratory equipment environment. That is one that is not only for research equipment in both the sciences and engineering, but in undergraduate instructional equipment. In engineering laboratories, as Don Weinert mentioned, it is deplorable in many institutions.

The Federal Government obviously cannot—or obviously should not, in my opinion—pick up the whole tab for this, but there is a lot of leverage that can be presented in appropriate programs to ensure that this does not happen again and that we stay on a better keel than we have in the past on that score.

Mr. **Boucher**. So your conclusion, as I understand it, then, is that we should be focusing on upgrading laboratory equipment for engineering education programs, but that the Federal Government should not exert a role in ensuring that faculty salaries are enhanced. Is that a correct statement?

Dr. **Lear**. That is my personal opinion on it. I think that the system is too pluralistic, too diverse, for the Federal Government to play an appropriate role in enhancing the salaries of engineering faculty within the institutions.

Mr. **Boucher**. Does everyone agree with that? Dr. Yankwich.

Mr. **Yankwich**. Mr. Chairman, I would like to comment on one aspect of the questions you addressed to Mr. Lear.

I think it is useful in this regard, particularly in the matter of mismatches between supply and demand and the faculty problem in colleges of engineering, to do a little historical sociology.

The problem that engineering has, among those at this table, is very different from that in the hard sciences and in the health sciences. The principal reason is that the sociology of industrial employment and the sociology of academic employment are no longer parallel. They were at one time; they now no longer are.

You remarked that it is a matter of the student who is approaching the baccalaureate degree making a choice whether he will go directly into industry--because the baccalaureate is still the entry-level degree for 85, 95 percent of engineering graduates—or make a commitment to academic work. Neither in the hard sciences nor in the health sciences must a commitment be made at that time, because the entry level, for example, in the practice of chemistry may nominally be the baccalaureate level. Certainly, there are things that baccalaureate chemists do in industry. But most trained scientists are engaged in research or development, and industry, at least in chemistry, in the period from 1915 to 1930, discovered how to use the Ph.D. The industries that employ large numbers of engineers are only now beginning to make that same kind of discovery, and it will take another 20 to 30 years for them to work out their own techniques.

In the meantime, this disjuncture will continue to exist, and I believe that both Mr. Lear and Mr. Weinert—and I certainly would agree with them—are not sufficiently clairvoyant to know how we can accelerate the closing of that gap. We are caught in an historic problem. There is no way out of it except to let time pass.

Mr. **Boucher**. Dr. Lear has made the suggestion that one appropriate Federal response to the shortage in engineering faculty is an upgrading of equipment for engineering education. I would be interested to know whether members of the panel can suggest other proper Federal responses to that problem.

Mr. **Weinert**. Well, I can pick up a little bit on that. Obviously, I agree with the need to do something about laboratory facilities, and I also agree with Dr. Lear that the Federal Government should really not get involved in setting faculty salaries. That is, again, the business of the marketplace.

He mentioned, and I would go further to say that there are a great number of things the Federal Government can do to create the kind of environment that might cause a 21- or 22-year-old young man or woman making the decision Dr. Yankwich just referred to to say, "Hey, I'd like to go on and become involved in the academic community and teach." Whether later downstream that advanced degree will even translate on into the practice at industry is something we have yet to see, and it will be a long time.

You can provide the kind of research funds and initiatives for fundamental engineering research that have been so successfully done with basic scientific research for years. We are going to have to do a little work figuring out just exactly what that is and how to go about it.

But there is one thing you can do to help create an environment that makes it look exciting and interesting to stay on and work in the academic environment. These kids watch their professors, and they know whether they are happy or unhappy with what they are doing. They watch the conditions under which they work. They look at the laboratories. They look at the paperwork. They hear him say, I can't be with you tonight because I've got to fill out all these Federal forms or whatever he is getting ready to do.

This is not a joke; this is true. This happens. I hear it related time after time after time. If they get a picture that teaching is not only not fun; it is a pain in the neck; and besides that—and I do not think this is primary consideration—besides that, it doesn't pay as well as something else might, then you aren't going to have a lot of them opting. I don't care how many faculty vacancies there are and what other devices you use.

The Federal Government can help create the right kind of environment. It can help provide exciting fundamental engineering research in institutions that are not now involved in it by the right kinds of grants and incentives. It can do a great deal in the lab area to leverage private sector funds that can help correct the lab problem. I don't think the Federal Government can begin to touch it on its own.

But again, I think we ought to remember that it is that overall environment and what the youngster observes as he is going through his bachelor's program that really has a greater influence on that decision than almost anything else. And if they see the right things, many of them will opt to go on and teach. If they don't, they are going to go out and try to make, quote, lots of money.

Mr. **Boucher**. Yes, Dr. Challoner.

Dr. **Challoner**. I might add some relevant comments. Even though it has been primarily engineering that we have been dealing with, I think there are a couple of things from the health sciences, with which I am most familiar, that are relevant. Dr. Yankwich's comments were right on in terms of historical perspective and the development of what I know of engineering.

An interesting, somewhat analogous, situation exists for nursing, which is currently in transition in the academic research world to having an increased number of Ph.D.'s on the faculty in health science centers in large universities. Ph.D.'s in nursing are some way analogous to the entry of the Ph.D. into engineering practice, and we are dealing with some of those same issues there.

In addition, I would emphasize the importance of the research environment as the Pied Piper for the young candidate for faculty scientific positions. That is as true in the health sciences as it is in engineering or any other place.

We in medicine have been dealing, as I have mentioned earlier, with the physician investigator, with a situation which for years is one in which, though the terminal degree has been an M.D. degree in both cases for practice and for research, there has been an economic disincentive for that M.D. to choose research.

So the individuals that do, do because of a real life commitment to that kind of intellectual activity, and the Federal Government, in that series of programs that I discussed with you, has specifically targeted certain areas along the way that the profession and its organizations and the NIH and ADAMHA have found to be hurdles necessary to get over and have provided programs which have helped a little bit with that hurdle. I think similar analyses in the development of these other areas are likely to be fruitful.

Thank you.

Mr. **Boucher**. I gather that the panel agrees that we do have a shortage in faculty positions that, if allowed to continue over the

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long term, would threaten the basic supply of engineering graduates; that it is not a proper Federal response to that condition to have the Federal Government supplement engineering faculty salaries; that it is a proper Federal response to provide the means for obtaining more modern equipment for engineering education; and that it is a proper Federal response to make the general atmosphere for research more attractive so that students will choose to enter that environment as opposed to going immediately into the private sector or, if they go into the private sector, that they may return in due course to participate in research.

How can we accomplish that last objective? What should the Federal Government do to make the research environment more attractive?

Dr. Yankwich.

Dr. **Yankwich**. Let me note that I believe all four of us have mentioned specifically the matter of costly instrumentation and other purely mechanical things that create the research environment in a physical sense.

I think in engineering the situation must be nearly as desperate as it is in physics and chemistry, where modern industrial practice does support a level of instrumentation sufficiently near the cutting edge in what we would call the production areas, the development areas, that no university, no engineering college, can afford to match.

That mismatch has varied in width, historically, but now it is very wide and the gap is accelerating. I believe that support of instrumentation programs in virtually all technical areas would be very helpful. It is sort of a lowest common denominator to all of our problems of a professional environment.

Dr. **Lear**. I would certainly agree on the instrumentation score and point out further that we are beginning to make some strides in a direction which I think would accomplish the objective that you suggested. For example, the Engineering Research Center concept which has come out of the National Science Foundation is a definite move in the direction to point out the unique capacity for research of a nature that is not done anywhere else, that can be done by the engineering colleges of the Nation. If that program comes to its full fruition, which we hope will be the case, that would be a major move in the right direction to do the sorts of things that Don Weinert said were part of the attractiveness of the teaching position itself. But beyond, of course, they have the base reason of being a source of research output in that unique area that engineering covers that we cannot do otherwise unless we do shore up that piece of the action.

I think some good moves have been made to start this not only in NSF but in terms of—and not only in terms of the Engineering Research Center program itself, but in terms of the change in concept within the Foundation of where engineering research lies in the scheme of things. I think that is improving, and if that continues, I see a future that will accomplish that particular purpose.

Mr. **Weinert**. I think there is probably not a need to discover a new wheel here. I do think that we have some very excellent things already underway, as Ed has pointed out, that, were they finetuned, and honed, and analyzed, there are some existing pro-

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grams in science that we ought to look at perhaps for engineering, and I certainly endorse your remarks in that regard—graduate fellowships, young investigator awards.

Of course, the centers of excellence, if they create this exciting, stimulating environment, will attract automatically topflight people. They will just want to go there because it is known all over the world or all over the country as a center of excellence in whatever—manufacturing, technology, or whatever.

I think many of the things that we have already discovered, packaged, finetuned, refined over time, may well address the issues we raise. I am not too sure you need to go out and seek some miraculous new program, certainly not a miraculous Federal giveaway program, because I don't think that is the answer.

Dr. **CHALLONER**. Just to continue the remarks, equipment and equipping of laboratories is certainly critical; the facilities issue is one that I am sure most of the members of this committee are well familiar with. That, I would emphasize for consideration, is a major part of the environment with which we are concerned.

I think you have heard fairly generally from the panel that we believe that the market should be the major controlling force in the manpower flows and productions that we are talking about. But in the kinds of markets that we are dealing with here at the graduate level, in the case of biomedical sciences, 10 years or so in the length from the first entry to the final product, with some fallout along the way, the information systems that allow a player in that market to make informed choices are critical. The better the job we can do in describing the economics and environment at each step, and the ultimate employment environment, it will help to have a more informed participant in the process.

That is one of the hopes, of course, for the Committee on Biomedical and Behavioral Research Manpower Needs, that if people pay attention to what is being said there—we had a fairly large postdoctoral pool, for instance, immediately post-Ph.D., for a period of years that was expanding; it was an indicator that there wasn't a market then for faculty employment out of that postdoctoral pool. Well, we are now beginning to see that contract for the first time, and the report that we will make to the Congress in another several months indicates that there are other factors, probably a decreased number of Ph.D.'s entering the pool now. So this kind of information is useful to faculties, universities, and participants, and the Congress can help there.

Dr. **YANKWICH**. May I add another comment on the supply?

Mr. **BOUCHER**. Yes, Dr. Yankwich.

Dr. **YANKWICH**. Strangely enough, we are going to come around eventually to addressing the subject of today's hearing, which is supply and demand, and perhaps I could start the ball rolling by speaking to one aspect of this.

Both Mr. Weinert and Dr. Challoner have mentioned time as a factor, and there are characteristic times for lots of the things that we are familiar with and by which we guide our lives. There is a circadian cycle of about 24 hours between sunrise and the following sunrise that governs lot of things. The time constant for undergraduate education is about 4 years. Things happen in about that kind of cyclicity. Shortages generally take a while to develop, but one of

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the real problems in the manpower area is when suddenly demand disappears with a short time constant and supply is geared to a much longer time base.

Recently in chemical engineering and in civil engineering, we have had this kind of disjunction where suddenly demand disappeared, and what one experiences then is one, two, or more totally lost generations to the profession, because by the time demand turns up again, those graduates of 2 or 3 years ago who weren't immediately placed aren't fresh any more. They are like fish; they aren't quite fresh enough.

If there is anything that the Federal Government could do to ballast this with a reserve postgraduate program such that these scientists and engineers were kept working not on the kinds of esoteric things that go on in university laboratories but things that go on in industrial, institutional, and national laboratories, it might help to provide underpinning so that these generations, all of whom were educated at very high cost to the public, directly or indirectly, would not be lost to their respective professions, as many of them are now.

Mr. **Weinert**. If we are back to supply and demand, Dr. Yankwich raised earlier, I think, the comment about precollege education. I have a feeling that the long-term solution to supply and demand in science, engineering, and technical fields in general lies there, even though I realize that that is not the specific purview of this task force and this committee.

In earlier discussions on this subject, I have raised that point again, and I think that there is a great deal the Federal Government can do in that area. Whether it is in the purview, again, of your task force or not, I am not sure, but programs to emphasize the importance of math and science at the precollege level and to create excitement and interest among youngsters at that level will carry on into college.

It will guarantee not only a high-quality pool of potential candidates in both areas, but it will be a push to the system. They will demand more involvement in science and engineering because they are excited and they are exposed and they are not afraid, and they understand the math.

One of the things that keeps a lot of them these days from pushing the system is that they don't know enough about it; they are afraid of it; they didn't have enough math; and they don't want to get into it. If you were to change that, if you were to create whole generations of highly literate youngsters in math and science in the elementary and high school level, that will push right on into the college and universities and, ultimately, right on into the engineering profession and into the various scientific disciplines. I really think, in the long run, that is the way to take care of the supply issue, and other things are manipulations to deal with median or short-term problems.

Mr. **Boucher**. What does the panel think that the role of continuing education should be, both with regard to engineering and the sciences, and does the panel believe that there are adequate continuing education programs in place today to meet the need that you perceive?

Dr. Yankwich.

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Dr. **Yankwich**. Well, I detected Dr. Challoner's eyebrow going up, and I really should have let him answer this first because I know of no profession represented at this table, other than medicine, in which, by law, there is a continuing education requirement. Even professional engineers, in most States, do not have a professional continuing education requirement that stands at law. The only profession that does in every 1 of the 50 States, incidentally, is optometry.

The American Chemical Society is a very substantial continuing educator. We have large programs. They are continually expanding as we discover ways of being more helpful. Many colleges and universities that have advanced programs in science find ways to make those programs available, not usually on a regular or simple basis, to science practitioners in industry who want to return to campus for a period of refreshment.

This is not a very practical way of doing things. The short-course kind of continuing education, things that an individual can do on his own time, either at work after hours or in his own home, are much more effective devices, and a number of the professional societies I know are active in developing things in this area, and the American Chemical Society has had a great deal of experience in doing so.

It is very important. It is the answer to the maintenance of currency, professional currency, in many, many areas, and there ought to be a lot more of it. Federal support of demonstration programs is already occurring through some of the programs of the National Science Foundation, because, in the application of new, instructional technologies perhaps being tried out in the elementary school or in the high school, it turns out that these have direct applicability to professional continuing education. It is just a question of providing the funds for the transfer to occur, an area in which a Federal role would be very much welcomed.

Dr. **Challoner**. I want to make sure that you understand the perspective in which I am discussing continuing education. I want to clearly separate continuing education for practicing health professionals from what we would call perhaps retreading of midcareer health scientists, health researchers, where very different processes, very different kinds of resources are needed.

One of the things that we don't know much about is the explanation for the productivity-versus-age curve looked at for scientists virtually of any kind. Certainly we know about the—at least it is not a myth—the early productivity of some of the mathematical scientists. Most of the people in the health professions and some of the other sciences peak somewhat later in terms of productivity, looked at from the point of view of publications. Then there tends to be a tailoff from about age 45 onward. We don't know what can be done, if anything, to change that tail, because we may be losing the opportunity for having a more productive faculty than is currently in place. Certainly there are a variety of retreading devices in place in most universities with graduate programs, in particular. It is the faculty sabbatical program, which is supported in many ways out of whatever resources the university itself brings to bear.

The Federal Government, in certain areas, does provide fellowship support for individuals to supplement their sabbatical experi-

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ence. But it may be that a closer look needs to be taken at a midcareer fellowship program for the retreading of all—not all, for individual faculty members that have an interest and do wish to keep up with their field or make a midcareer correction in course in terms of bringing new techniques to their own bench.

Mr. **Weinert**. As Dr. Yankwich pointed out, only one State, Iowa, actually has specific requirements for continuing education for engineers. Several States mention it. But there are two kinds that are at issue, and I think I would point out that one is specifically job related, more immediate.

There are a large number of opportunities to obtain specific technical knowledge and information that is related to one's perceived immediate job requirements and needs, and by far the largest provider in that area, overwhelmingly so, is industry itself. Industry employs 75 percent of all the engineers and, far and away, is the biggest provider of continuing education, again focused on their needs as the employer.

The more important issue, or at least one potentially more important, has been alluded to twice now, and that has to do with what I would call long-term, career development and maintenance of competency in the long haul. You might even use the "retread" word. Maybe that applies, I don't know.

There is an area where we in the profession have not yet been able to get our act together and decide what really is needed. We think there is a role here for the Federal Government working in partnership with the engineering profession, at any rate, to investigate this area, perhaps develop some demonstration programs, to figure out a way that, if the demand drops out of the bottom for civil engineers or petroleum engineers overnight, what can we do to most effectively use those resources.

Oh, they will find other jobs, and they do. The question is, are they really being effectively utilized, and we all know the answer is no. This retread, this long-term, continuing education need, is an area that I think the Federal Government, working with the private sector, should be able to do something about, and we all need to work on it; I think we need to go in partnership on it.

Dr. **Lear**. As I have noted in my written testimony, I feel that the whole area of continuing education, of lifelong learning, is a key issue over the years ahead in how we manage our science and engineering resources in this Nation.

I feel that the very best we can do for an undergraduate student in engineering—as Don says, we have the bulk of them going to work with a bachelor's degree—the very best we can do in that 4 years is to give them a kit of tools and some of the basic elements that underlie all engineering, some understanding of how these are applied to specific problem-solving situations within a discipline, and then to give them a feel that lifelong learning is a must, and an understanding that change is the norm and that they are going to have to stay alive and awake by that process.

There are lots of opportunities for continuing education of people in the engineering profession, as has been mentioned. The industrial is a large component of that; the professional societies; all the universities themselves. Almost universally, they have a continuing education program in which they present programs in some marketplace demand approach for industry, usually in their own areas. But it is a very hodge-podge, ad hoc sort of system, one which does not have a great deal of interconnectedness, and I am not sure what the Federal role might be here.

Nam Suh at the National Science Foundation, as you perhaps know, in the engineering directorate, has suggested that perhaps a Federal role might be, working through the engineering societies, to be a coordinator of the continuing education efforts in engineering within the country. Perhaps something of that sort could be developed. It is certainly in the drawing-board stage now, not that well developed at all. But it is a problem which is going to be more and more acute as we go on in time, and I think it is going to require that we do it on a planned basis rather than an ad hoc basis in some fashion.

Mr. **Boucher**. Let me ask the panel one final question before we adjourn. In terms of long-term trends, I wonder if you would comment on the effect that advances in technology in the private sector will have on the demand by the private sector for bachelor-level engineers. For example, we are seeing advances in computer-aided design and computer-aided manufacturing. Will that serve the purpose of decreasing the demand for bachelor-level engineers? And do you think such a reduction, if it occurs, would be remarkable?

Dr. **Lear**. Since I have the large microphone, I will start.

Let me be sure I understand the exact nature of your question. You are asking whether the increase in demand for people at another level might decrease the demand for the bachelor's level in engineering?

Mr. **Boucher**. Well, I am wondering whether advances in technology in the marketplace would have the effect of decreasing the demand by the private sector for engineers. Perhaps some of the work that engineers do in design and drafting—when you walk into a factory or any kind of manufacturing facility, you normally find rooms of engineers with drawing boards. Now, to the extent that that work is done in the future by technology as opposed to being done by individuals, will there be a decrease in demand for engineers?

Dr. **Lear**. Well, this comes into the prognostication area, of course, but I think history is a good teacher here. We have certainly had advances in technology over the years. We think that the ones that we are into now are much different, much more sophisticated, than we have had in the past.

I am not so sure that is always true, but history has said that over the years we have had a continual increase in the need for a technological base in the work force that is there in our industrial complex, and the drawing board illustration, for example—I think if you went into most industrial organizations now, you wouldn't find those. That doesn't mean, though, that those industries have not increased the work force, the number of the engineers that they need to do particular jobs that are different from the ones in the past and more sophisticated than ones in the past, but certainly, there is an increasing component of technological need.

We have talked about ups and downs in engineering demand. There is a very attractive curve which, unfortunately, I don't have here in large enough form to show you, anyway, that shows, going back to about 1930, that the engineering output from the colleges has gone up and down, but it has gone up and down above and below a very rapidly rising demand curve. It is a demand curve because engineering unemployment has never been higher than about the 2- or 3-percent range.

So what this says is that the demand has been increasing steadily with changes in technology, and we have certainly seen some changes that have, on the surface of it—the automation, for example, would have said we don't need as many people. But that simply has not been the case. My assessment is that we are going to continue to need more and more people. And, incidentally, we are not nearly to the state that a lot of the other industrialized countries are in terms of the number of engineers in our population, as a fraction of our population, that we find elsewhere.

Mr. BOUCHER. I gather your conclusion is that advancement in technology will increase the need for engineers rather than decrease it.

Mr. Weinert.

Mr. WEINERT. The last time I had a conversation with some industry leaders on a subject relating to this, they were lamenting the fact that down on the plant floor, where the manufacturing process is going on, it is so complicated and so complex now that they really need lots of process control engineers, lots of engineers in places that they never had engineers before. They are saying: "Gee whiz, we just have a big shortage of engineers down on the plant floor," because they never really thought about working down there.

I am also reminded that when the hand calculator started off, a lot of my compatriots said, Well, now that the slide rule is no longer in vogue, we really will be able to do a lot more, each individual engineer will do a lot more; and when the computer came in, the next thought was, Well, look how much more you can do with the computer—computer-aided graphics, computer-aided design. What you do is you find more things to do with these marvelous tools, and the demand curve keeps going up. So I don't think there is any danger that the bottom is going to fall out because we figure out a way to increase the productivity of engineers by a factor of two or three. What it means is that we will find two or three more things to do.

Mr. BOUCHER. Very good.

Mr. Packard, do you have questions?

Mr. PACKARD. I have none, and I am sorry I could not be here for the full hearing; I have had other hearings, but I appreciate it.

Mr. BOUCHER. I would like to thank our panel of witnesses for their very excellent testimony today and their comprehensive responses to questions.

The record will remain open for additional questions which will be submitted by other members who were not in attendance today, and I would appreciate the witnesses' responding to those in writing as they are received.

This task force now stands adjourned until 9:30 tomorrow morning in this room.

[Whereupon, at 11:07 a.m., the task force recessed, to reconvene on Wednesday, July 24, 1985, at 9:30 a.m.]

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SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

WEDNESDAY, JULY 24, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 9:37 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Good morning.

Today the task force continues its hearings on the subject of supply and demand of scientists and engineers.

Our first panel will discuss the equity of opportunity in education and careers for women and minorities in science and engineering. In addition, the panel members will comment on any special factors that have particular effects on equity and opportunity in science and engineering.

The second panel will focus on the adequacy of current data concerning the science and engineering work force education and manpower and consider our ability to predict future needs confidently. The panel will also consider the adequacy of data concerning the quality of science and engineering personnel and the perceived need for improvements in the data base.

Because we have two panels this morning, we will ask the witnesses to be brief in order to leave time for questions from the task force members.

PANEL 1

The first panel, which is already in place, will be Dr. Shirley Malcom of the AAAS in Washington; Mr. Newt Watson of the Xerox Corp., and Dr. Sue Berryman with the Rand Corp.

Dr. Malcom, we would be pleased to hear from you at this time.

STATEMENT OF DR. SHIRLEY M. MALCOM, PROGRAM HEAD, OFFICE OF OPPORTUNITIES IN SCIENCE, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC

Dr. Malcom. Thank you very much.

I am Shirley Malcom, Program Head of the Office of Opportunities in Science of the American Association for the Advancement of Science. The office is involved in activities to promote the full participation of minorities, women, and physically disabled persons in careers in science and engineering. I am also the chair of the National Science Foundation Committee on Equal Opportunities in Science and Technology. I am here today, however, as an individual. The views that I express are my own and do not represent the position of either the AAAS or the NSF CEOST committee.

I really appreciate the opportunity to participate in the hearings today which are focused on supply-and-demand issues for scientists and engineers. This specific panel has been asked to explore the Federal programs and special efforts to promote equity of opportunity in education and careers in science and engineering.

I will touch on five points in my opening statement, and then I will stop. The first, I think, is that we have to figure out why we have to be concerned about women and minorities in science and engineering. What is at stake? I think that this is something that has not really been clear in the past. What is at stake is more than just an issue of social justice. It is more than just an issue of conscience. It is more than just a matter of fulfilling the basic ideals upon which this country was founded of equality of opportunity. It is an issue that strikes at the heart of the enterprise of science and technology itself.

The second point that I would make is that most of the topics that are to be covered by this task force in its deliberation over the next year really have equity components that need to be explored in the context of those particular panels.

The third point is that the science policy study must look below the graduate and postdoctoral levels if it is to seriously examine the educational barriers that women, minorities, and physically disabled persons face in the pursuit of science and engineering careers.

No coherent program exists to address the problems faced by these groups in the pursuit of careers in science and engineering or in the advancement of persons from these groups presently in science and technology careers.

And, finally, the programs created in the Federal structure to address the problems of equity of opportunity to education and careers in science and engineering have been characterized for the most part by inadequate funding levels, little commitment to sustained, long-term support, and marginal positioning within the various agencies. Most have been token efforts, applied as Band-Aids to slow the hemorrhage of human talent from the pipeline leading to science and engineering careers.

I have found it interesting that many of the developed nations, not just the United States, have started to look at the issue of women in science and technology. To name a few, we have had studies in Canada, the United Kingdom, Sweden, and Denmark. Their interest in promoting the increased participation of this particular group in the scientific and technological educational pipeline was because of their needs to staff and people economies that are based in technology. I think that it is interesting to note that and to take a lesson from the programs as they are established in these other countries, and that is that they do tend to be much more coherent; they are centrally focused; and it is clear that they understand what is at stake.

Thank you.

[The prepared statement of Dr. Malcom follows:]

TESTIMONY OF
SHIRLEY M. MALCOM

Program Head, Office of Opportunities in Science
American Association for the Advancement of Science

I am Shirley M. Malcom, Program Head of the Office of Opportunities in Science (OOS) of the American Association for the Advancement of Science (AAAS). This office is involved in activities to promote the full participation of minorities, women, and physically disabled persons in careers in science and engineering. I am also chair of the National Science Foundation (NSF) Committee on Equal Opportunities in Science and Technology (CEOST). I am here today, however, as an individual. The views that I express are my own and do not represent the position of the AAAS or NSF CEOST.

I appreciate the opportunity to participate in the hearings today which are focused on supply and demand issues for scientists and engineers. This specific panel has been asked to explore the federal programs and special efforts to promote equity of opportunity in education and careers in science and engineering.

I want to elaborate on five points here today. I will comment upon each of these in turn.

1) Equity of opportunity in science and technology is not just a social justice issue.

2) Most of the topics to be covered by this task force in its deliberations have equity components which should be explored.

3) The Science Policy Study must look below the graduate and postdoctoral levels if it is to seriously examine the educational barriers that women, minorities and physically disabled persons face in the pursuit of science and engineering careers.

4) No coherent program exists to address the problems faced by these groups in the pursuit of careers in science and engineering or in the advancement of persons from these groups presently in science and technology careers.

5) The programs created in the federal structure to address the problems of equity of opportunity to education and careers in science and engineering have been characterized for the most part by inadequate funding levels, little commitment to sustained, long-term support, and marginal positioning within the various agencies. Most have been token efforts, applied as

Band Aids to slow the hemorrhage of human talent from the pipeline leading to science and engineering careers.

Equity of Opportunity and the Science Policy Study

I have been extremely interested in the monumental and forward looking task that the House Committee on Science and Technology has undertaken. There is a clear need to look again, in a comprehensive way, at the complex set of science policy issues tackled in the 1945 Bush report to the President, Science - The Endless Frontier. I daresay that the task undertaken in 1985 is made substantially more complex because of the gigantic strides we have made in science and technology in the past 40 years, the vastness of the scientific and technological enterprise in the U.S. and around the world, the implications and consequences of this tremendous knowledge explosion, and the complex social, cultural, and political milieu in which all of this has occurred. The discussion of equity in which this panel has been asked to engage is but one example of this changed social, cultural and political context. I doubt that this topic would have been considered a major discussion point in a report written in 1945.

It is imperative that, in the current discussions, the Task Force go beyond equity of opportunity concerns and deal with the ways in which the participation of women, minorities, and disabled persons in science and engineering permeates the full range of issues in which it is interested.

a) The goals of federal science policy. How do we arrive at our goals for science? How active a role do minorities, women and disabled scientists and engineers play in this goal setting process, given that the process results in priority setting and resource allocations that affect all groups within the society? How are issues of differential impacts and relation to other national goals addressed if these groups have restricted access to the process?

b) The future of U.S. science. Can the U.S. maintain a position of leadership in science while ignoring the talent of 65 percent of its human resource base? How can we cultivate the talent base of women, minorities and disabled persons as a source of renewal and new ideas for the future of U.S. science?

c) Institutional framework for science and engineering. Anticipating the future demographic shifts in this country (smaller overall numbers of 18 year olds and increasing proportions of minorities in the school age population), should our universities be concerned about the diversity as well as the quality of its faculty in science and engineering? Should there be special programs of support for undergraduate institutions that produce disproportionately high numbers of women and minorities who persist to doctorates in science and engineering, e.g. women's college and minority institutions?

d) Education and manpower. If the talents of women, minorities and disabled persons are not fully utilized, how will the U.S. increase the number, and quality of U.S. citizens (1) needed by government and industry; (2) among Ph.D.'s for faculty positions in areas of shortage, e.g., in some fields of engineering and in computer science; and (3) among precollege teachers of science and mathematics? Without these groups, how will the highest quality be maintained in all fields of science and engineering?

e) Supporting programs for women, minorities and physically disabled persons. How does program development to address the participation of women, minorities and physically disabled persons proceed in different agencies? What is the effect of the different processes, strategies and requirements on the intended beneficiaries? Are there clear areas of unmet needs? Do inadequate levels of support for the core science program (as opposed to project oriented research) impair the science programs of minority institutions? Do we have adequate data to assess the levels of current federal support received by minorities, women and physically disabled persons? Can we determine their present status in the educational pipeline, with levels of detail necessary to inform policymaking and program development?

f) Future science policymaking. What has been the congressional role in program development and support for efforts to increase the participation of underutilized groups in science and engineering? And finally, what should the future of congressional involvement be, given the significance of equity of opportunity to the full range of science policy agenda items?

Clearly, these questions cannot be dealt with during the limited time allocated to today's discussions. They deserve attention by each panel in turn as the Task Force conducts its work over the next year and a half.

The Nature of the Problem

One needs only to go into the laboratories of our major research institutions, into our industries or federally funded research and development centers to "eyeball" the problem. Our university engineering and physics labs tell the same story, as do our high school physics and computer classes: Female and minority students are present in low numbers relative to their overall numbers in the student body, or in the population at large. In the science and engineering workforce, these groups are underrepresented relative to overall population numbers, labor force participation rates, and participation in professional and technical workforce (Table 1).

American Indian, Black, Mexican American, and Puerto Rican males and females are underrepresented and underutilized in science and engineering. Members of these groups who enter science and engineering careers do not advance as rapidly, tend to have lower salaries, and are more likely to be unemployed or underemployed than their white male counterparts. White females are underrepresented and underutilized, receive lower salaries, and are much more likely to be in non-tenure track, off-line positions, unemployed or underemployed than all their white male counterparts. These facts hold after standardizing for field, sector of employment and years of experience. (Women and Minorities in Science and Engineering, January 1984; the biennial report to the Congress prepared by the National Science Foundation).

The lack of sufficient data and information on disabled scientists and engineers makes it difficult to report on their status from a comfortable base of statistics, but case studies of individual scientists suggest that problems exist for this group as well. A greater problem may be access to science and engineering education at the college and graduate levels and access to the quality and quantity of precollege science and

Table 1

PERCENTAGE OF U.S. MINORITIES IN VARIOUS POPULATION GROUPS
(Data are for 1980 unless otherwise noted)

	White	Black	Hispanic	Asian	Indian	Foreign
U.S. Population	83.2	11.7	6.5	1.6	0.6	3.0
Elem/Secondary Enrollment	73.3	16.1	8.0	1.9	0.8	
High School Graduates 1978	82.3	11.7	4.2	2.8	0.7	2.7
Undergraduate Enrollment	80.6	10.1	4.2	2.3	0.7	2.1
Graduate Enrollment	81.9	5.5	2.2	2.1	0.4	7.9
First Profess. Enrollment	89.3	4.6	2.4	2.2	0.4	1.0
Total Enrollment 1982	80.7	8.9	4.2	2.8	0.7	2.7
Bachelor Degrees 1981	86.4	6.5	2.3	2.0	0.4	2.4
Master's Degrees 1981	82.0	5.8	2.2	2.1	0.3	7.5
Ph.D.s 1983	76.9	3.2	1.9	3.3	0.3	14.4
Sci/Eng Ph.D.s 1983	73.9	1.8	1.5	4.3	0.2	18.3
Employed Sci/Eng 1982	90.3	2.6	2.2	4.5	0.4	

Source: Scientific Manpower Commission.

mathematics education needed to pursue careers in science and engineering by physically disabled youth.

Although the Task Force has signalled its intention to deal with education issues closer to the end of the pipeline (at graduate and postdoctoral levels), it is unrealistic to seriously examine the barriers that women, minorities and physically disabled persons face in the pursuit of science and engineering careers by looking only at the last 5 to 7 years of a 21+ year educational process. The pipeline to a Ph.D. in science or engineering is a long one, with hurdles that must be crossed at every phase. The science and engineering pipeline for women and minorities is most full in high school although, even at this point, many from these groups have effectively lowered their probability of science and engineering degree attainment by course choices made or academic tracks selected as early as middle school or junior high school (Table 2). Failure to take the full complement of college preparatory mathematics and science courses in high school reduces even further the numbers of females and minorities in the pipeline. According to Berryman, from high school on, there is only leakage from the pipeline for all students.

Wanted: A Policy and A Plan

The issues related to equality of opportunity in education and careers in science and engineering have been at the margin in most of the federal science agencies. They have been based on perceived compatibility with the missions of the agencies, not necessarily on the priority of needs of the affected groups. While the efforts have not been duplicative, they have left gaping holes in programming. There has been no overall agenda development, policy and program formulation and coordinated response to that agenda. The programs, many of them congressionally directed, have tended not to be developed or nurtured by the agencies beyond the experimental, model, or pilot phase. Effective "models" have been discontinued without transfer or further dissemination of the lessons learned. Inadequate levels of support make efforts appear cosmetic, insincere, or set up for failure.

Minority and women scientists and engineers are not present in policymaking and decisionmaking positions in sufficient numbers so that they can affect the course of

Table 2

PERCENTAGES OF HIGH SCHOOL SENIORS TAKING SPECIFIC MATHEMATICS AND SCIENCE COURSES IN 1980*

Course	All Seniors	Male	Female
Algebra I	79	79	79
Algebra II	49	51	47
Geometry	56	58	55
Trigonometry	26	30	22
Calculus	8	10	6
Physics	19	26	14
Chemistry	37	39	35

Course	Hispanic	Black	White	American Indian
Algebra I	67	63	81	61
Algebra II	38	39	50	32
Geometry	39	38	60	34
Trigonometry	15	15	27	17
Calculus	4	5	8	5
Physics	15	19	20	17
Chemistry	26	28	39	24

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* From NCES, High School and Beyond.

discussion, or question the setting of priorities or the allocation of resources in the agencies.

While mainstreaming has been and continues to be a goal, the careful blending of both targeted and mainstreaming efforts must persist for the near-term if we are to achieve equity of opportunity goals.

There continues to be a reluctance on the part of agencies to challenge the research universities, so we live with a situation where tax dollars support non-equitable practices within these institutions -- where women and minorities receive less support for graduate study in science and engineering from research assistantships; where they are trained but not hired, or hired but not promoted; where women are allowed to stay on in many institutions in "soft money" positions, but are not allowed to apply for money in their own names, thus "ghosting" their way through the federal grantmaking system; where their salaries are lower from entry point through the academic ranks.

The programs for women and minorities seem to enjoy undue levels of scrutiny considering the small amounts of money involved. The programs are evaluated, monitored and asked to prove their worth in unreasonably short spans of time.

Despite the rather critical remarks made about agencies' handling of many programs for women and minorities, the efforts themselves have been valuable. For example, support of research on women and mathematics by the National Institute of Education was critical in the development of interventions to address the low levels of mathematics coursetaking by female precollege students. This behavior change by female students was a necessary first step to keeping their options open and, along with career exploration programs funded by federal and private sources, probably led to the increases in engineering enrollments and degrees seen for women in the late 1970's to the present (Equity and Excellence: Compatible Goals). On the other hand, no such comprehensive program of research on minorities and mathematics has been undertaken, and we know much less about how to affect mathematics achievement for American Indian, Black, Mexican American and Puerto Rican male and female students.

There are targeted efforts to increase support to Historically Black Colleges and Universities growing mainly out of the President's Initiative, but it is not clear that the institutions serving other minorities are, can, or should be offered the same menu of efforts. Although several agencies have considered targeting research support to women's colleges, this has not been pursued. Women and minorities tend to be inadequately supported in graduate study, more frequently reporting "self" sources of support. Minorities have problems finding support for undergraduate study as well, and many dropout because of these financial difficulties. Majority institutions have become a revolving door for so many minority students where they are "the only" in a department, without a psychological and academic safety net, without faculty who can see beyond the rough to the diamond, beyond the lack of experience to the talent waiting to be nurtured and claimed. I know; that student was me. I have also met that student over and over again among minority scientists and engineers -- we are the survivors, who all too often make it "in spite of" and all too seldom make it "because of."

The individual programs undertaken by the various science agencies have, for the most part, been effective in promoting equity if effectiveness is measured specifically in light of individual program goals. Collectively, however, the programs do not add up to the array of efforts at appropriate levels of support and commitment to achieve equity of opportunity for education and careers in science and engineering.

In addition to the specific science and engineering efforts, other federal programs and practices, not specifically aimed at these fields, provide needed financial and academic support to minority, handicapped and disadvantaged students at the college level — systems of student financial assistance and special student services. Any reduction of commitment to such programs or to the enforcement of civil rights laws in our colleges and universities seriously undermines the integrity of both government and the educational institutions to the fulfillment of their promises to and in keeping with their roles in the larger society.

Although the barriers to science and engineering careers for women, minorities and physically disabled persons are high, they are not insurmountable. We have learned much over the past 15 years about effective programs for these groups, both in school and out of school and at all educational levels. We know a lot about what needs to be done, but few steps have been taken toward these goals. There is no ownership of the problems; in most cases there is little acknowledgement that there are problems. We have not had the will, the plan, the money nor the action on equity issues partly because they have been seen as the problems of the affected groups. Perhaps the restatement of the problem of equality of opportunity in the larger context of this

Science Policy Study is what is needed to broaden the national discussion on "whose problem it is." When seen as a part of the larger discussions of human resource development, the supply and demand for scientists and engineers, goal setting for science in the U.S., and differential impacts of science and technology in society — equity in science ceases to look like a marginal issue and takes its rightful place along side these other mainstream concerns. The time is past for a piecemeal approach to achieving equality of opportunity in education and careers for women, minorities, and physically disabled persons. We need a clearly stated policy, a strong agenda for coordinated action and research, the leadership, the will, and the money to carry out that agenda.

Some Specific Barriers to the Science and Engineering Education of Women, Minorities and Disabled Persons

a) Women

Pre-college

- Classroom practices by teachers that do not support female students' science interest, e.g., failure to ensure that females as well as males have an opportunity to gain access to science equipment and are encouraged to participate fully
- Lower and different expectations regarding science and math achievement for girls by parents, teachers, counselors, and, ultimately, by both female and male students themselves
- Failure to take the amount and kind of courses in mathematics and science needed to pursue science and engineering careers
- Lack of access to computer training, especially computer programming and advanced courses

College

- Lack of encouragement of women's interest in science primarily due to the absence of an academic and social support network, including access to successful female role models
- Lack of undergraduate research opportunities
- Lack of encouragement to pursue postgraduate studies

Graduate and Postdoctoral

- Limited opportunity to obtain research assistantships and "good" postdoctoral appointments
- Absence of successful female role models in the research setting.
- Lack of opportunity for socialization in the profession

b) Minorities

The problems need to be considered separately for the different racial/ethnic groups and for males and females in these groups.

Pre-college

- Low quality of education in the schools which minorities attend.
- Failure to take adequate levels of science and mathematics needed to pursue science and engineering fields
- Few successful role models present
- Low expectations of youth by teachers, counselors and, eventually, by the students themselves.
- Poor or no counseling concerning possibilities for college work in science and engineering
- Little knowledge of career options

College

- Inadequate financial support for college study
- Lack of academic and personal support systems in science and engineering
- Minimal opportunity for undergraduate research experience
- Lack of encouragement to pursue post-graduate studies

Graduate and Postdoctoral

- Lack of financial support for graduate study, especially as research assistants
- Few minority faculty present as role models in the research university
- Lower and different expectations for future success in research
- Lack of adequate opportunity for socialization to the profession

c) Physically Disabled Persons

The problems differ by type of disability and age of onset.

Pre-college

- Lack of quality science instruction appropriate to sensory or motor impairment
- Lack of emphasis on science and mathematics instruction in special education settings
- Lack of (denial of) access to the laboratory and/or to science experiences, such as field trips
- Low expectations for students in terms of careers in science and engineering by teachers, parents, counselors

College

- Inaccessible science buildings, laboratories or programs
- Lack of knowledge about specific accommodations needed by disabled students in science and engineering
- Lack of coherent support program for disabled science and engineering students

Graduate

- Lack of specific adaptations in the laboratory (to equipment and facilities)
- Lack of a coherent set of policies governing financial support (federal, state, rehab, institutional aid) for graduate study in science (i.e., that four years of undergraduate support is insufficient for a science career and that the operative degree for a researcher is the Ph.D.)

The Federal Response to Barriers

There are excellent programs that address some of the barriers cited in this testimony. Some examples are given below.

a) Programs to break into the grants system of the science agencies

- National Institutes of Health (NIH)
  - Academic Research Enhancement Awards (AREA) support health-related research by faculty members in institutions which normally do not receive biomedical research grants.

  - Extramural Associates Program to acquaint faculty from small, women's and minority institutions with NIH and other federal grants programs. Uses IPA for short-term leave from home institution at NIH.

- National Science Foundation (NSF)
  - Minority Research Initiation (MRI) Program provides support for minority full-time faculty who are seeking federal support for the first time.
  - Research Opportunities for Women (ROW) Program provides support for women who have not been a principal investigator on a Federally funded project.

b) Programs to support graduate education in science, engineering and biomedicine

- NIH & Alcohol, Drug Abuse, and Mental Health Administration (ADAMHA)

  - Minority Access to Research Careers (MARC) Programs providing support for minority faculty and graduate and undergraduate students

- NSF
  - Minority Graduate Fellows Program - Members of minority groups underrepresented in science are eligible to apply if they are planning to work on a master's or doctoral degree in mathematical, physical, biological, engineering, or social sciences or history or philosophy of science.

- Department of Education
  - Graduate and Professional Opportunities Program to support study by women and minorities in fields non-traditional to these groups (status uncertain in 1986 budget).

c) Programs to provide support for research and/or scientific infrastructure in institutions that educate significant numbers of minority students.

- NIH & ADAMHA

  - Minority Biomedical Research Support (MBRS) Research Centers (new program) is designed to increase minority institutions' abilities to procure biomedical grants and attract competitive biomedical scientists.

- NSF
  - Research Improvement in Minority Institutions Program seeks to strengthen the research capability of minority institutions which have graduate science programs.

- U.S. Department of Agriculture (USDA)
  - Support of second Morrill Act institutions (Historically Black Landgrant Colleges)

- Department of Education
  - Minority Institutions Science Improvement Program (MISIP) (the only science program at the Department) provides grants in order to strengthen science education at minority institutions.

- National Aeronautics and Space Administration (NASA)
  - Graduate Student Researchers Program - A student's faculty advisor submits a proposal in a research area identified by one of the NASA field centers. Once the proposal is selected, a graduate student in aerospace science and technology conducts his/her thesis research at the NASA center.

d) To provide adaptation for research equipment for use by disabled graduate students, researchers or other personnel employed on research grant.

- NSF
  - Research Facilitation Award for special equipment or assistance necessary to enable a handicapped individual to participate in an NSF grant.

e) Programs to introduce minority and/or female students to careers in science and engineering.

- NIH, Department of Defense (DOD)
  - Research Apprenticeship Programs provide minority high school students an opportunity to work with an actual researcher.

- Department of Energy
  - Pre-Freshman Engineering Program (PREFACE) provides funds to attract minority and female junior and high school students to pre-engineering enrichment studies.

The listing provided above is by no means exhaustive; a more complete list of programs for minorities, women and disabled persons is being prepared at this time by staff at the National Science Foundation in response to a request from the President's Science Advisor, Dr. Keyworth. The fact that no listing has existed previously and that no single federal source was aware of the complete range of federally supported efforts speaks to the problems I have noted.

Although the listing of programs may seem impressive at first reading, the funding levels in most of these programs is quite low. The level of effort does not compare favorably with resource levels in non-targeted programs which tend to serve women and minorities quite poorly. The numbers of persons affected are small compared with those who could benefit from such programs. There is often poor articulation between programs and not all fields of science are served equally well.

Perhaps the discontinuity and marginal nature of focused federal programs for women and minorities are best illustrated by the programs that are not among those listed as currently in operation. These include programs that existed at the NSF prior to 1981: various programs for women in science, the Resource Centers for Science and Engineering program, and the specially focused components of the Student Science Training and Undergraduate Research Participation programs. These efforts were not discontinued because they were ineffective, or because they were not needed. It is time to review what we have done in the past and to reestablish and support dissemination of the most promising efforts. It is time to call upon all federally supported programs for the retraining of teachers to attend specifically to equity issues, out of consideration for the majority of their potential student population. It is time to take a leadership role, in saying to states, local government, industry and our educational institutions that, without women and minorities, the numbers no longer add up; we cannot continue to meet our scientific and engineering manpower needs.

Building the pool of talented minority and female students who complete high school with the quality and quantity of science and mathematics courses necessary to pursue careers in science, engineering and biomedicine is a goal which still alludes us. And as we disagree on the role of federal, state and local governments, the national need to utilize fully the talent of 65 percent of our students goes unmet. I urge this Task Force to rethink its concentration on education issues at the graduate and postdoctoral levels to the exclusion of the full set of pipeline issues, especially as these relate to providing full opportunities to women, minorities and disabled persons in science and engineering.

Mr. FUQUA. Mr. Watson.

[A biographical sketch of Mr. Watson follows:]

Name: Newt Watson.

Address: 8 Whitecliff Drive, Pittsford, NY 14534.

Employer: XEROX Corporation (since 1974); Manager, A.A./Equal Employment Opportunity of the Corporations Reprographic/Technology Business Group.

Previous positions held: Midwest Regional Personnel Manager; Marketing Personnel Operations Manager; Distribution Operations Personnel Manager; Marketing Consultant; and Compensation Analyst.

Previous employment: Zenith Electronics Corporation.

Positions held: Assistant to Labor Relations Director; Plant Training Coordinator; and Manager, Corporate Training and Development.

Education: Southeast College, Chicago, Illinois Business Administration—1968; University of Chicago, MBA 1974; Finance and Marketing.

Professional associations: National Action Council for Minorities in Engineering (NACME).

Personal: Married, three children; Bryan, Alan, Kelly.

STATEMENT OF NEWT WATSON, MANAGER, AFFIRMATIVE ACTION/EQUAL EMPLOYMENT OPPORTUNITY, XEROX CORP., WEBSTER, NY

Mr. WATSON. Good morning, and thanks, also, for giving me an opportunity to share my views on the subject of minorities and females in the engineering discipline.

I am aware of our time parameters, so I would like to move right into the subject matter. I want to touch on the subject matter from three aspects, and the first is the problem as I see it or have elected to define it.

I would like to spend some time addressing the issue of women and minorities in science and engineering. We frequently read about the shortage of women and minorities in the scientific and engineering disciplines. On July 14, the *Chicago Tribune* ran an article titled "Women Called to Engineering." The article pointed out the fact that Japan has twice the number of engineers as the United States, and male enrollment alone in our engineering disciplines is not sufficient to bridge the gap. The article suggests tapping the female resource, and I would add that we should also make a more concerted effort to tap the black and Hispanic resources of this country.

In trying to understand the issue of shortages of women and minorities in science and engineering, we must closely examine those antecedent conditions which gave rise to the present condition. This examination is important because I feel that in order to achieve equality of opportunity, we must first address the issue of equality of condition. If future direction is therefore geared toward equality of opportunity in science and engineering and nothing more, then I would argue that such efforts will fail. I feel that while equality of opportunity for women and minorities is a necessary condition for eventually arriving at a state of parity, it is not a sufficient condition. Failure to specifically address the antecedent conditions will ultimately lead to failure in our efforts to reach parity.

If, for example, colleges and universities establish a strict policy of equal opportunity relative to admittance and said that whoever scores the highest on an entrance exam would be admitted, many women and minorities would continue to be locked out. The failure with this "equal opportunity" approach is that it does not address the conditions as to why women and minorities have historically failed to be represented in these disciplines. The only way in which this inequality of opportunity will be corrected is through special dispensations of justice; that is, justice must be the balancing and prevailing force when the natural market forces are noncorrecting. And I maintain that education, and public education in particular, requires nonmarket decisionmaking.

Up to this point, I have assumed that we are in agreement that women and minorities should be fully represented in these technical fields at least in proportion to their representation in the population or the work force. If we are to correct the problem, then we must look at the nurturing processes for women and minorities vis-a-vis majority males. Since there is no scientific evidence which says that women and minorities belong to a different species, we must conclude that all human beings are of the same species bearing common traits. Thus, we are all created equal with respect to being of a common species and possessing common traits. The reason that minorities and women are disproportionately represented in any field is due to the manner in which they are treated during the course of their development. More directly, women and minorities are not, by nature, ill prepared for these fields; rather, they are nurtured differently and, consequently, find themselves disproportionately represented in these fields.

Since I have strongly suggested that there are major problems in our nurturing processes and the antecedent conditions for equality, I suggest a focus on the extent to which Federal policies and programs perpetuate inequality of condition. I will return to this when I discuss some recommendations at the end of my talk.

Turning to industry for a minute, my position is as affirmative action manager for the Xerox Corp., so I am primarily concerned with maintaining contact and rapport with minority nonprofit organizations as well as academia.

The industry is commonly viewed as a provider of goods and services. However, industry is also dependent on some of their needs from other institutions. One of industry's needs is customer or human resource needs. Industry, frequently in large measure, depends on academia to provide certain human resources. In a free-market economy, industry would "go someplace else" to satisfy those needs if they were not being satisfied by academia. I feel that academia has failed to satisfy industry's needs relative to women and minorities in the engineering and technical fields. Consequently, industry has had to develop elaborate training centers to help try to meet those needs.

Some of the issues that we face, or industry faces, in trying to attract minorities in engineering would be as follows: in the recruiting area, it is much more difficult to recruit minority women—minorities, period—and females in the technical disciplines: One, simply because of the supply. Additionally, minorities tend not to sign up on college campuses as majority males do because many of them have been coached through high school and already have alternatives laid out for them at the time of graduation.

In regard to search firms, we frequently use search firms, with marginal success. Again, the issue is one of supply, so the search firms are not as effective as they are with majority candidates.

Concerning staffing, it is not unusual for a company to have incremental staffing to ensure development and maintenance of proper relationships.

In terms of geographic preferences, there are issues in terms of having minorities and females located from urban areas into predominantly white areas. Companies do special things to try to assure that there will be a good life, if you will, as a result of relocating.

Turning to premium pay, because of the supply/demand situation, women and minorities can demand a premium starting wage rate. Industry must balance this against the potential morale problems internally and salary compression programs.

On the subject of Affirmative Action/Equal Employment Opportunity guidelines, companies strive to meet the letter and spirit of the law relative to hire, development, and promotion. This means hiring a good ratio of minorities and women in every job category. This also poses a problem because of the supply/demand situation.

Most of the issues that I have identified relate to costs, which means that there is an incremental cost that corporations frequently must bear as a result of the shortage of supply of women and minorities.

Let me now address recommendations for Government support. As mentioned in my earlier remarks, the primary focus of the Government should be toward establishing an equality of condition. Too many of our urban schools still graduate functional illiterates, where our suburban schools graduate students having some of our highest scores in the country. The quality of education provided at the elementary and high school levels must be addressed.

The Government could at least consider some of the following things: increasing the funding to schools which have special programs in early development of math and science; sponsor urban school teachers in continuing education during the summer. Many of our urban school teachers of math and science have not had a math and science course themselves since high school.

Also, Government could encourage industry and academia to initiate preengineering programs to motivate our female and minority youth toward the technical fields. Xerox Corp. is engaged in a couple of what I consider model programs. However, there are other companies who also have some very good programs and have had some good successes.

Since the majority of black engineers come from historically black colleges, the Government should specifically focus on ways to support these black schools and their engineering programs. Specifically, increase the amount of Government research to these schools; work on one or more of these schools as a center of excellence in fields such as robotics, plastics, fiber optics, et cetera.

There are a couple of more recommendations that I had, but I want to move right into the summary and leave some time for questions.

In my opening remarks, I addressed the issue of inequality of opportunity and equality of condition. Although we did not answer this very specific question—How much equality does justice require?—a principle would state that no member of society should have so much that others are deprived of that minimum amount which is necessary for a comfortable life. I maintain that, due to inequality of condition, we do have a situation where thousands of members of our society do not have that minimum amount to satisfy the basic needs of a more comfortable life. This committee then has an opportunity to help recalibrate those wheels of inequality. In the word of our great Dr. Martin Luther King, Jr., this committee has an opportunity to move from a stage of intellectualizing affirmative action to actualizing affirmative action, for when we do, minorities benefit, industry benefits, and the world society benefits.

To a large degree, my focus has been on education, as I feel that education is a most critical antecedent condition that needs addressing. It is very difficult for industry to correct the problem when there is an insufficient supply of human resources possessing requisite skills. Public education grew up and largely replaced the private school in the 19th century because citizens believed that there were positive externalities associated with an educated populace, and that equality of opportunity was a right that could be guaranteed only by such a system. While many people still feel strongly about these objectives, we know that our urban schools from coast to coast are graduating functional illiterates. We are faced with preserving the principles upon which our education was founded and solving the problem of public education. The problem is very difficult because it is solved out of the marketplace. The process of nonmarket or nonfree enterprise decisionmaking requires special dispensations of justice.

I am convinced that this committee has the influence to bring about positive change relative to representation of women and minorities in the scientific and technical disciplines.

Thank you.

[The prepared statement of Mr. Watson follows:]

UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE AND TECHNOLOGY
WASHINGTON, D.C. 20515

JULY 24, 1985

STATEMENT OF PROPOSED ORAL TESTIMONY

SUBMITTED BY:

NEWT WATSON
MGR., AFFIRMATIVE ACTION/EQUAL EMPLOYMENT OPPORTUNITY
XEROX CORPORATION
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INTRODUCTION:

THANK YOU FOR GIVING ME AN OPPORTUNITY TO SHARE MY VIEWS ON THIS VERY IMPORTANT SUBJECT WITH THIS ESTEEMED GROUP COMMISSIONED BY THE HONORABLE CONGRESSMAN, DON FUQUA OF FLORIDA. I SHOULD MENTION THAT ALTHOUGH I DO WORK FOR XEROX CORPORATION, MY VIEWS DO NOT NECESSARILY REFLECT THE VIEWS OF THE CORPORATION ON THIS SUBJECT.

I AM AWARE OF OUR TIME PARAMETERS AND I WOULD THEREFORE LIKE TO QUICKLY MOVE INTO THE SUBJECT MATTER BY DISCUSSING FIRST, THE PROBLEM INTELLECTUALIZED; SECOND, INDUSTRY'S CHALLENGE: THIRD, RECOMMENDATIONS FOR GOVERNMENT SUPPORT AND FINALLY, A BRIEF SUMMARY.

THE PROBLEM INTELLECTUALIZED:

I would like to spend some time addressing the important issue of Women and Minorities in Science and Engineering. We frequently hear or read about the shortage of Women and Minorities in the Scientific and Engineering disciplines. On July 14, the Chicago Tribune ran an article titled, **"Women called to Engineering"**. The article pointed out the fact that Japan has twice the number of engineers as the United States and male enrollment alone in our engineering schools is not sufficient to bridge the gap. The article suggests tapping the female resource, and I would add that we should also make a more concerted effort to tap the black and hispanic resources of this country.

In trying to understand the issue of shortages of Women and Minorities in Science and Engineering, we must closely examine those antecedent conditions which gave rise to the present condition. This examination is important because I feel that in order to achieve **equality of opportunity,** we must first address the issue of **equality of condition.** If future direction is therefore geared towards equality of opportunity in Science and Engineering and nothing more, then I would argue that such efforts will fail. I feel that while equality of opportunity for Women and Minorities is a necessary condition for eventually arriving at a state of parity, it is not a sufficient condition. Failure to specifically address the **antecedent conditions** will result in ultimate failure in our efforts to reach parity.

If for example, colleges and universities establish a strict policy of equal opportunity relative to admittance and said those who score highest in entrance exams are admitted, many Women and Minorities would continue being left out. The failure with this "equal opportunity" approach is that it does not address the conditions as to why Women and Minorities have historically failed to be represented in these disciplines. The only way in which this inequality of opportunity will be corrected is through special dispensations of **justice.** That is, justice must be the balancing and prevailing force when natural market forces are non-correcting; and I maintain that education and public education in particular requires non-market decision making.

Up to this point I have assumed that we are in agreement that Women and Minorities should be fully represented in these technical fields at least in proportion to their representation in the population or workforce. If we are to correct the problem, then we must look at the **nurturing processes** for Women and Minorities vis a vis majority males. Since there is no scientific evidence which says that Women and Minorities belong to a different species, we must conclude that **all** human beings are of the same species bearing common traits. Thus, we are all created equal with respect to being of a common species and possessing common traits. The reason that Women and Minorities are disproportionately represented in any field is due to the manner in which they are treated during the course of their development. More directly, Women and Minorities are **not**, by nature, ill prepared for these fields; rather, they are **nurtured** differently and consequently, find themselves not properly represented in these fields.

Since I have strongly suggested that there are major problems in our nurturing processes which are the antecedent conditions for equality, I suggest a focus on the extent to which federal policies and programs perpetuate institutional **inequality of condition**. I will return to the government's role when I discuss recommendations.

THE INDUSTRY CHALLENGE:

While Industry is commonly viewed as the provider of goods and services, Industry itself is a **customer** for many things. One of Industry's needs as a customer is human resources. Industry frequently depends in large measure on academia to provide certain human resource needs. In a free market economy, Industry would "Go Someplace Else" to satisfy its human resource needs if academia were not satisfying those needs. I feel that academia has failed to satisfy Industry's needs relative to Women and Minorities in technical fields. Consequently, Industry has developed elaborate training centers which not only teach functional skills, but fundamental courses in principles of Math and Science.

The problem for Industry is very similar to that of a competitive product scenario. That is, in the development of a new product, companies will try and assess an unmet customer need. Satisfying that need means profits to the Corporation. Industry is currently experiencing an unmet need relative to Women and Minorities in Scientific and Engineering fields. Consequently, Industry must develop special strategies and programs which will assure a stream candidates until a state of equilibrium is achieved. This is a major challenge because most high tech firms, such as AT&T, G.E., IBM, Kodak, DuPont, Honeywell, etc., are looking for the same kinds of candidates as Xerox. Each company is looking for a strategy which will yield a **competitive advantage** in attracting Women and Minorities.

Some of the strategies and problems encountered by companies in their efforts to achieve a balanced workforce include the following:

o Recruiting (College) -

It is much more difficult to recruit Women and Minorities in the technical disciplines than it is to recruit majority males. This is due to their small representation of major colleges and universities. Also, many of these individuals have been sponsored and "tracked" by corporations through high school and do not feel compelled to engage in the standard campus interview process.

o Search Firms -

While many companies use search firms to help meet their needs of Women and Minorities, the payoff is frequently marginal in that these firms frequently charge a premium and the candidates themselves may charge a premium. The key problem however seems to be one of supply.

- Staffing -

  It is not unusual for a company to have incremental staffing to ensure development and maintenance of proper relationships between company academia and professional associations.

- Geographical Preferences -

  Blacks in particular are not indifferent to relocating. Industry sometimes goes to great lengths to assure Blacks they will be satisfied living in a predominately white community.

- Premium Pay -

  Because of the supply/demand condition, Women and Minorities can demand a premium starting wage rate. Industry must balance this against potential morale and salary compression issues.

- AA/EEO Guidelines -

  Companies strive to meet the letter and spirit of the law relative to hire, development, promotion and retention. This means hiring a good ratio of Women and Minorities in every job category --- Technical and Non-Technical.

- Upward Mobility -

  Government regulations require representation through the organization. Companies must therefore be very aggressive at the entry level to assure a feeder base for the upper level positions.

- Costs -

  Most of the above actions translate into incremental costs for the Corporation.

RECOMMENDATIONS - GOVERNMENT SUPPORT:

As mentioned in my early remarks, a primary focus of the government should be towards establishing an equality of condition. Too many of our urban schools still graduate functional illiterates where our suburban schools graduate students having some of the highest scores in the country. The quality of education provided at the elementary and high school levels must be addressed.

Additionally, the government could:

- o Increase funding to schools which have special programs in early development of math and science.
- o Sponsor urban school teachers in continuing education during the summer. Many of our urban teachers of math and science have not had a math or science course since they graduated from high school!
- o Encourage industry and academia to initiate pre-engineering programs to motivate our female and minority youth towards the technical fields. Xerox is engaged in two model programs, PRIS^{2}M and Science Consultant which other companies might learn from. Other companies too have good community programs.
- o Since the majority of black engineers come from historically black colleges, the government should specifically focus on ways to support these black schools in their science and engineering programs. Specifically;
    - Increase the amount of government research going to these schools.
    - Work to make one or more of these black schools a center of excellence in a particular field, e.g., robotics, plastics, fiber optics, etc.

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- Support upgrading of school equipment with government equipment donations.

- Make development of Women and Minorities in science and engineering a national priority.

- Where Federal funds are already allocated, require those institutions to develop a Long Range Plan which has as its goal, full representation of Women and Minorities in Technical and Non-Technical disciplines.

SUMMARY:

In my opening remarks, I addressed the issue of inequality of opportunity and equality of condition. Although we did not answer the very difficult question, "How much equality does justice require?" a principle would state that no member of society should have so much that others are deprived of that minimum amount which is necessary for a comfortable life. I maintain that due to inequality of conditions, we do indeed have a situation where thousands of our members of society do not have that minimum amount to satisfy the most basic needs for a comfortable life. This National Committee on Science and Technology has an opportunity to help recalibrate the wheels of inequality. In the words of the great Dr. Martin Luther King, Jr., this committee has an opportunity to move from a stage of intellectualizing Affirmative Action to actualizing Affirmative Action. For when we do, Women and Minorities benefit, families benefit, industry benefits and the world society benefits.

To a large degree my focus has been on education because I feel that early education is a most critical antecedent condition that needs addressing. It is very difficult for industry to correct the problem when there is an insufficient supply of human resources possessing requisite skills. Public school education grew up and largely replaced the private school in the nineteenth century because citizens believed: a) that there were positive externalities associated with an educated populace; and b) that **equality of opportunity was a right** that could be guaranteed only by such a system. While many people still feel strongly about these objectives, we know that our urban schools from coast to coast are graduating functional illiterates. We are faced with preserving the principles upon which public education was founded and solving the problems of public education. The problem is very difficult to solve because it is solved out of the marketplace. The process of non-market or non-free enterprise decision-making requires special dispensations of justice.

I am convinced that this committee has the influence to bring about positive change relative to the representation of Women and Minorities in Scientific and Technical disciplines.

Mr. **Fuqua**. Thank you very much, Mr. Watson.

Dr. Berryman.

STATEMENT OF DR. SUE E. BERRYMAN, THE RAND CORP., WASHINGTON, DC

Dr. **Berryman**. Good morning, Mr. Chairman and members of the Task Force on Science Policy.

My testimony today reflects my own views, not necessarily those of either the Rand Corp. or the Rockefeller Foundation, which funded the analyses on which my comments are based.

I understand that the task force is concerned with postsecondary, especially graduate education in science. Many of my remarks today involve precollegiate education and individuals at the precollegiate stages of their education. I suggest that my points are nonetheless relevant to your purview. Factors at earlier stages of the educational process profoundly affect the issue that we are discussing today, the underrepresentation of women and minorities at the graduate level.

I have submitted a report for the record. Let me start by summarizing my conclusions.

First, if you are going to make a difference in the number of women and minority scientists and engineers, intervene early. "Early" means the elementary, middle school, and high school grades.

Second, gradually convert the advanced high school mathematics courses in high school from electives to requirements for the college preparatory curriculum.

Third, consider how the Nation might substantially improve the content and spirit of mathematics and science instruction throughout the grades, not just in high school, which is where we are particularly concerned today. Family and cultural influences depress the participation of women and minorities in science and engineering. We have reason to think that the logical institution for counterbalancing these influences at early ages—in other words, the school—is not delivering quality mathematics and science instruction at any level for any of our children, let alone for female and minority children. Improving the quality of instruction may not be sufficient but is necessary to countering these pervasive family and cultural influences.

Let me now give you the highlights of the document that I submitted for the record.

If you want to reduce attrition from the minority or female group that is preparing to enter science and engineering, you can target these efforts at any point in the educational process. The data show that we lose individuals from school and from the quantitative fields of study at all stages of the process from high school through the Ph.D. However, if you want to increase the number of minorities and women studying science and engineering, you should target your efforts before and during high school.

Unlike the humanities, law, and the social sciences, the quantitative fields such as the physical and biological sciences, mathematics, engineering, and medicine are unforgiving of the individual's prior educational choices. Although we find that students can move back and forth between scientific and nonscientific interests during the elementary, middle, and early high school years, individuals who do not complete the advanced mathematics sequence in high school such as algebra II and the calculus have almost a zero probability of obtaining a bachelor's degree, master's degree, or doctorate in a quantitative field. Ironically, today's high school tradition of offering the advanced mathematics courses as electives operates not to expand the student's options but to foreclose them for those who do not complete this sequence.

Students in the college preparatory curriculum should be required to take the full high school mathematics sequence to maintain their post-high school options. These requirements should be introduced gradually to minimize the disruption for students and the schools. High schools already confront a shortage of qualified mathematics and science teachers, and increasing the mathematics graduation requirements will exacerbate the shortage.

The second point is that the underrepresented subgroups in science and engineering—women, blacks, Hispanics, and American Indians—differ in how they become underrepresented. They therefore differ in their needs. A subgroup such as blacks can end up underrepresented in quantitative fields for either or both of two different reasons: its members leave school earlier than the average for all groups, or those who stay in school select a quantitative field of study less frequently than the average for all groups. These factors—earlier exit from school and less frequent choices of quantitative fields—combine in different ways to produce the ultimate underrepresentation of the different subgroups.

For example, blacks leave school at rates higher than average at several points in the educational process: From high school graduation throughout the Ph.D. They lose field ground just as they lose degree attainment ground at several points in the process. At the B.A. level, the percent of blacks choosing quantitative fields is 60 percent of the national average; at the M.A. level, it is 40 percent; and at the Ph.D. level, it is down to 33 percent. When we put blacks' lesser persistence in school with lower rates of choosing a quantitative field, the situation gets worse. We find that relative to a white in 1978–79, a black was only 33 percent as likely to have received a quantitatively-based B.A., 20 percent as likely to have received a quantitatively-based M.A., and 16 percent as likely to have received a quantitatively based Ph.D.

Women, on the other hand, have about the same school exit rates as men until the Ph.D. However, they are no more than half as likely as men to get the B.A., M.A., or Ph.D. in a quantitative field.

The third point is that the subgroups differ in why they make the educational choices that they make. If we don't understand the dynamics that underlie these choices, we cannot fix the problem that these choices produce, nor can we form realistic expectations for the timing and magnitude of payoffs from our solutions.

It is increasingly clear that minority and female underrepresentation among quantitative degrees is tightly fused to some of the most deep-seated questions that a society can pose. For women the pattern is relatively clear. Gender differences in grade 12 mathematics achievement are primarily attributable to differences in boys' and girls' participation in elective mathematics. However, since boys and girls do not differ significantly in average mathematical achievement at grade 9, grade 9 mathematics achievement does not explain subsequent gender differences in the decision to pursue elective mathematics courses.

How useful the individual expects mathematics to be for reaching his or her educational and career goals does strongly affect the decision to participate in high school elective mathematics courses. The more useful the individual expects mathematics to be, the more high school mathematics he or she takes.

Thus, gender differences in occupational plans become key to understanding gender differences in decisions to take the advanced high school mathematics sequence. Girls' occupational plans depend on how they expect to split their time as adults between the labor force and the home. Girls who expect to spend more time in the labor force and less time in the home are more apt to choose traditionally male occupations such as engineering and ones that require substantial educational effort, such as taking the elective high school mathematics sequence.

In sum, the key for women seems to be their career choices, their decision to take the junior and senior high school mathematics and science sequence being related to these choices. The career choices themselves seem to reflect how women resolve the conflict between achievement in the labor force and family responsibilities. As long as girls expect to assume the major child-rearing responsibilities of their children, we can expect them to be less likely than boys to choose quantitative occupations that require major educational and labor force commitments.

Boys and girls enter high school with approximately equal average mathematical achievements but different career preferences. The racial and ethnic groups at grade 9 differ both in their career preferences and in their average mathematical achievements. Two momentous factors contribute separately to the relationships that we observe between ethnicity, mathematical achievements, and career preferences. These are the factors of culture and social class.

English, Australian, Canadian and American studies all indicate that culture and social class, independently, affect family behaviors that in turn powerfully affect children's school performances. These family patterns include how much the parents expect the child to achieve, the language models that the parents use, the academic guidance that the parents provide the child, how active the family is both indoors and outdoors, the nature and quality of toys, games, and hobbies available to the child, and the work habits of the family. Lower-class families of different ethnic origins vary more in these family behaviors than their middle-class counterparts. Being middle class probably marks not only a socioeconomic position but also assimilation into the main stream and therefore more homogeneous family behaviors.

Different ethnic groups also work at somewhat different jobs, partly because they have different residential patterns and therefore different labor market niches, for a variety of reasons—cultural, the openness of certain occupations to talent, regardless of the individual's racial or ethnic origin. The subgroups also seem to use different occupations and industries as upward mobility avenues.

For example, the Asian Americans use the small business avenue—restaurants, shops that sell imported goods, green grocers in New York City, and quantitative professional technical jobs. The Irish, on the other hand, used the civil service in the big cities where they were concentrated as upward mobility avenues. Children's occupational horizons tend to mirror the occupational options of their parents and their subgroup. Again, ethnic differences in children's occupational plans and attainments are more pronounced for children from the lower-class than from the middle-class families.

Studies of the choice of quantitative majors in college show results consistent with these multinational studies on ethnicity, social class, family behaviors, children's school performances, and occupational preferences. Analyses of 1980 American data show that being second-generation college—a characteristic that tends to mark middle-class origins—not only increases, but entirely equalizes, choices of quantitative majors among white, black, American Indian, Chicano, and Puerto Rican college freshmen.

For women, then, the challenge is to keep their occupational options open as long as possible. As girls grow up, they often wish to or have to change the time split between the labor force and home that they anticipated as adolescents and on which they predicated their initial occupational and educational choices. For the underrepresented minorities, the challenge is a familiar, but nonetheless profound, one: starting, expediting, or supporting the upward mobility process.

Let me close by returning to my three conclusions. First, if you are going to make a difference, intervene early. Second, if you want to keep the posthigh-school options open for all youth, not just women and minorities, convert the advanced high school mathematics courses from electives to requirements for the college preparatory curriculum. Do it on a publicly announced but gradual schedule to avoid exacerbating the shortage of qualified mathematics and science teachers.

And, third, consider how the Nation might substantially improve the quality of mathematics and science instruction throughout the grades, not just in high school. We have to rely on our schools to counterbalance the pervasive family and cultural influences on girls' and minorities' mathematical and scientific interests and abilities. As I noted earlier, we have reason to think that our schools are not delivering quality mathematics and science instruction at any level for any of our children. We have a variety of options. For example, we can try a small core of gifted mathematics and science teachers that travel among the elementary school classes. This strategy finesses the problem of the average female elementary schoolteacher who, as signaled by the choice of this occupation, tends to be less comfortable with the typically male worlds of science. We can use forgiveness of Federal educational loans to attract young and enthusiastic scientists and mathematicians into teaching. Certain States, such as Virginia and North Carolina, are already creating special science, technology, and mathematics high schools, although there is considerable room for experimenting with who gets access to these special resources.

I thank you for your time.

[The prepared statement of Dr. Berryman follows:]

TESTIMONY BEFORE THE TASK FORCE ON GOVERNMENT SCIENCE POLICY OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY, U.S. HOUSE OF REPRESENTATIVES

Sue E. Berryman
The Rand Corporation

July 24, 1985

Mr. Chairman and Members of the Task Force on Science Policy:

My testimony today reflects my own views, not necessarily those of either The Rand Corporation or The Rockefeller Foundation, which funded the analyses on which my comments are based.

I understand that the purview of the Task Force is the post-secondary, especially the graduate level, of education. Many of my remarks today involve pre-collegiate education and individuals at pre-collegiate stages of their education. Nonetheless, I suggest that my remarks are relevent to your focus because factors at the earlier stages in the educational process profoundly affect a problem of concern to you--the under-represention of women and minorities at the graduate level--and the potential effectiveness of government policies aimed at alleviating this problem.

I have submitted a report for the record. Let me start by summarizing my conclusions.

First, if you are going to make a difference in the number of women and minority scientists and engineers, intervene early. "Early" means the elementary, middle school, and high school grades.

Second, gradually convert the advanced high school mathematics courses in high school from electives to requirements for the college preparatory curriculum.

Third, consider how the nation might substantially improve the content and spirit of mathematics and science instruction throughout the grades, not just in high school. Family and cultural influences depress the participation of women and minorities in science and engineering. We have reason to think that the logical institution for counterbalancing these influences at earlier ages--the school--is not delivering quality mathematics and science instruction at any level for any of our children, let alone for female and minority childen. Improving the quality of instruction may not be sufficient, but is necessary to countering these pervasive family and cultural influences.

Let me now give you the highlights of the document that I submitted for the record.

If you want to increase the number of minority and women scientists and engineers, you should target your efforts before and during high school. Although students are able to move back and forth between scientific and non-scientific interests during the elementary, middle, and early high school years, students who did not complete the advanced mathematics sequence in high school are virtually unable to pursue quantitatively-based fields of study after high school. If you want to reduce attrition from the group preparing to become scientists and engineers, you can target these efforts at any point in the educational process: we lose individuals from school and from the quantitative fields of study at all stages of the process from high school through the Ph.D.

Unlike the humanities, law, and the social sciences, the quantitative fields--such as the physical and biological sciences, mathematics, engineering, and medicine--are unforgiving of the individual's prior educational choices. Specifically, we find that individuals who do not complete the advanced mathematics sequence in high school, such as algebra II and the calculus, have almost a zero probability of obtaining a bachelor's degree, master's degree, or doctorate in a quantitative field. Ironically, today's high school tradition of offering the advanced mathematics courses as electives operates, not to expand the student's options, but to foreclose them for those who do not complete this sequence.

Students in the college preparatory curriculum should be required to take the full high school mathematics sequence to maintain their post-high school options. These requirements should be introduced gradually to minimize the disruption for students and schools. High schools already confront a shortage of qualified mathematics and science teachers, and increasing the mathematics graduation requirements will exacerbate the shortage.

The under-represented subgroups in science and engineering--women, women, blacks, Hispanics, and American Indians--differ in how they become under-represented; they therefore differ in their needs. A subgroup, such as blacks, is under-represented in a field for either or both of two reasons. Its members leave school earlier than the average for all groups, or those who stay in school select a quantitative field of study less frequently than the average for all groups. These factors--earlier exit from school and less frequent choices of quantitative fields--combine in different ways to produce the ultimate under-representation of the different subgroups.

For example, blacks leave school at rates higher than average at several points in the educational process: from high school graduation through the Ph.D. They "lose" field ground just as they lose degree attainment ground: at several points in the process. For example, at the B.A. level, the percent choosing quantitative fields is 60 percent of the national average; at the M.A. level, 40 percent; and at the Ph.D. level, 33 percent. When we put blacks' lesser persistence in school together with lower rates of choosing a quantitative field, we find that, in 1978-79, relative to a white, a black was only 33 percent as likely to have received a quantitatively-based B.A., 20 percent as likely to have received a quantitatively-based M.A., and 16 percent as likely to have received a quantitatively-based Ph.D.

Women, on the other hand, have about the same school exit rates as men until the Ph.D. However, they are no more than half as likely as men to get the B.A., M.A., or Ph.D. in a quantitative field.

The subgroups differ in why they make the educational choices that they make. If we don't understand the dynamics that underlie these choices, we cannot fix the problems that these choices produce, nor can we form realistic expectations for the timing and magnitude of yields from our solutions.

It is increasingly clear that minority and female underrepresentation among quantitative degrees is tightly fused to some of the most deep-seated questions that a society can pose. For women the pattern is relatively clear. Since boys and girls do not differ significantly in average mathematical achievement at grade 9, grade 9 mathematics achievement does not explain subsequent gender differences in the decision to pursue elective mathematics courses. Gender differences in grade 12 mathematics achievement are primarily attributable to differences in boys' and girls' participation in elective mathematics.

However, how useful the individual expects mathematics to be for achieving his or her educational and career goals does strongly affect the decision to participate in high school elective mathematics courses. The more useful the individual expects mathematics to be, the more high school mathematics he or she takes.

Thus, gender differences in occupational plans become key to understanding gender differences in decisions to take the advanced high school mathematics sequence. Girls' occupational plans depend on how they expect to split their time as adults between the labor force and the home. Girls who expect to spend more time in the labor force and less time in the home are more apt to choose traditionally male occupations--such as engineering--and ones that require substantial educational effort, such as taking the elective high school mathematics sequence.

In sum, the key for women seems to be their career choices, their decision to take the junior and senior high school mathematics and science sequence being related to these choices. The career choices themselves seem to reflect how women resolve the conflict between achievement in the labor force and family responsibilities. As long as girls expect to assume the major child-rearing responsibilities of their children, we can expect them to be less likely than boys to choose quantitative occupations that require major educational and labor force commitments.

Boys and girls enter high school with approximately equal average mathematical achievements, but different career preferences. The racial and ethnic groups at grade 9 differ both in their career preferences and and in their average mathematical achievements. Two momentous factors contribute to relationships among ethnicity, mathematical achievements, and career preferences: culture and social class.

English, Australian, Canadian, and American studies indicate that culture and social class each affect family behaviors that in turn powerfully affect children's school performances. These family patterns include how much the parents expect the child to achieve, the language models of the parents, the academic guidance that they provide the child, how active the family is--both inside the home and outdoors, the nature and quality of toys, game, and hobbies available to the child, and the work habits of the family. Lower class families of different ethnic origins vary more in these family behaviors than their middle class counterparts. Being middle social class probably marks not only a socio-economic position, but also assimilation into the mainstream and therefore more homogeneous family behaviors.

Different ethnic groups work at somewhat different jobs. These differences become mirrored in the occupational horizons and attainments their children. Again, the ethnic group differences in occupational plans and attainments are more pronounced for children from lower class than from middle class families.

Studies of the choice of quantitative majors in college show results consistent with these multi-national studies on ethnicity, social class, family behaviors, children's school performances, and occupational preferences. Analyses of 1980 American data show that being second-generation college--a characteristic that tends to mark middle class origins--not only increases, but entirely equalizes, choices of quantitative majors among white, black, American Indian, Chicano, and Puerto Rican college freshmen.

For women the challenge is to keep their occupational options open as long as possible. As girls grow up, they often wish to--or have to--change the time split between the labor force and home that they anticipated as adolescents and on which they predicated their occupational and educational choices. For the under-represented minorities the challenge is a familiar, but nonetheless profound, one: starting, expediting, or supporting the upward mobility process.

And thus, I return to my three conclusions. First, if you are going to make a difference, intervene early. Second, convert advanced high school mathematics courses from electives to requirements for the college preparatory curriculum. Do it slowly but on a publicly announced schedule to avoid exacerbating the shortage of qualified mathematics and science teachers.

And third, consider how the nation might substantially improve the quality of mathematics and science instruction throughout the grades, not just in high school. We have to rely on our schools to counterbalance the pervasive family and cultural influences on girls' and minorities' mathematical and scientific aptitudes. However, we have reason to think that our schools are not delivering quality mathematics and science instruction at any level for any of our children, let alone for female and minority childen. We can try a small core of gifted mathematics and science teachers that "travel" among the elementary school classes. This strategy fineses the problem of the average elementary school teacher who, by virtue of having chosen this occupation, tends to be less comfortable with science and mathematics. We can use forgiveness of federal educational loans to attract young and enthusiastic scientists and mathematicians into teaching. We are already trying science and technology high schools, although there is considerable room for experimenting with who gets access to these resources.

I thank you for your time.

PANEL 1 DISCUSSION

Mr. FUQUA. Thank you very much, Dr. Berryman and our entire panel.

I gather from the comments that all three have made that we really have two problems, two different problems, one which Mr. Watson mentioned in the urban school areas and ghettoes and so forth where I guess a large percentage of blacks and Hispanics may reside. There is an inherent social problem associated with that. And then, Dr. Berryman, I think you pointed out the problem with women, white women—and I assume it would include black, also—that wanted to go into science and engineering, because of a lot of complexities of deciding whether to go into that or take the more traditional route.

We have been concerned about that. This committee started a women and minorities program in the National Science Foundation several years ago to try to enhance bringing that about. But while we have the jurisdiction of science education, our primary concern of these hearings has been in the graduate areas. But you pointed out, I think, very carefully the importance of starting early. It really starts in the high school or the elementary school. We have tried to address that in the math and science education bill that was enacted last year and passed out of this committee in 1983, for reteaching or—not reteaching but remedial courses for science and math teachers to come back, summer camps for students, scholarships for people that would go into science and math education, to teach. And it is a very serious problem.

I think what we are finding in our elementary and secondary schools is a situation of inadequate qualified teachers or those certified in those fields. I was wondering, since two of you come from industry, what is the private sector doing to attract more women and minorities into science and engineering, because I think it affects the private sector, too, because you are one of the beneficiaries of that?

Mr. **Watson**. Yes; there are some very specific things that the Xerox Corp. is engaged in, and some of these things are in concert with some of the other companies in the neighboring area.

One, for example, we have a program that is called Science Consultant Programs. We use a number of our scientists and engineers on a voluntary basis to go into the inner schools of the Rochester, NY, area and conduct science experiments.

We totally fund this, we develop the kits within our plant, we develop the curriculum, and we actually have the scientist go into the classroom with the teacher and conduct experiments there with the students in elementary school to help develop their interest in science.

We also have a program that we title PRISM, which is a program for students that have been identified as gifted students in math and science. We go into the classrooms, also, and work with those students.

Mr. **Fuqua**. This would be like the Merit scholars?

Mr. **Watson**. Similar to the Merit scholars, yes. This summer we have probably 28 of those students at Xerox. We make sure that their assignments are in the technical areas, not in the office area but in the labs and working along with engineers so that again they would become reinforced into the importance of what science is all about, and these are students who probably will go on to college.

We are working, as I said, with some of the companies in the area on these programs. We have also been in conversations with the University of Wisconsin at Madison with regard to having high school students come into the university during the summer and get some exposure into math and science and what it is like to be on a college campus, and of course, we are looking at funding some of those kinds of things, also.

So there are a number of things that we are doing in a program area and continually dialoging with the chamber of commerce, with the school district, because we are very, very serious about the situation, of course. We need minority and female engineers. Those are some of the things.

Mr. **Fuqua**. Dr. Berryman.

Dr. **Berryman**. The Rand Corp. does not do probably as much, certainly as much, as Xerox. It does have a graduate Ph.D. program called the Rand Graduate Institute which is a public policy Ph.D. program.

We use the resources, the staff of that college, as it were, or university, right within the corporation to teach students who are going on to college—these are minority young people who come for the summer between their senior year of high school and their first year of college—and we use the faculty there to upgrade their quantitative skills and give them some training in economics.

As I recall, these are youngsters who are anticipating going on in economics as a B.A. program. To my knowledge, that is all that we do rather specifically in this area, other than train individuals at the Ph.D. level, but that is a general public policy program. It is a very quantitative program.

There are certainly efforts, I know, to bring in as many women and minorities to that program as they can, but the program is relatively small, and I don't think it is making an enormous dent in the national problem.

Dr. MALCOM. While I am not from industry, I do have some information about industry support for these kinds of efforts.

Part of that comes about from a study that my office did as part of the effort of the National Science Board Commission on precollege education in mathematics, science, and technology. We looked at a whole range of intervention programs that had been undertaken for women and minorities and tried to figure out what it was about the ones that worked that made them work.

In the process of surveying this—I think it was about 300 programs—we also asked them what their funding sources were, and I would say that industry has been fairly generous in these kinds of programs. For example, they support the entire minorities in engineering effort through the National Action Council for Minorities in Engineering. They support the entire thing, and we are talking about millions of dollars for a fairly long period of time. They recognize it as in their self-interest to do this.

The problem with it is that it is the nature of the funding that they oftentimes deliver to the projects. They tend to be project related, to bring students in for such and such a period of time, or to loan scientists or these kinds of things.

The core operating support for most programs is what is the thing that holds the program together, but it is also often the thing that most funders are least willing to support—the people, the staff who have to go out and recruit the students or work with the teachers or what have you.

So I would say that the scorecard is mixed. On the one hand, they have been quite generous in terms of their support for some of the programs, but I think that it has been a matter of more what they are able and willing to give as opposed to what needs to be given.

Mr. FUQUA. Dr. Berryman, you mentioned the fact that women were less inclined because of being a wife or mother or whatever. Is that beginning to change now as we see more career couples together? The birth rate is definitely on the decline. We see two-career families, both professionals. Is that beginning to change?

Dr. BERRYMAN. Yes, it is. I think that we are just starting to see the results of that, but it is beginning to change.

One of the factors that is driving that change, ironically—in some studies that we have done, it shows us—is divorce in the family. Where the daughter was being raised by a mother, by a female head of the household, essentially, she was much more likely to choose a traditionally male occupation, much more likely to be somewhat more skeptical about marrying early, about having children early and so forth, so as we are getting these structural changes in the society, I think we can expect to see, across time, still more changes in the direction of moving into male occupations, which include the quantitative fields that we are talking about today.

Mr. **Fuqua**. Are there any programs—excuse me.

Dr. **Malcom**. I would just like to make a tail-end comment onto Sue's remarks, and that is that right now the choice point occurs so early that you are not mature enough to decide whether you are really going to try to combine family and career or go for a career or go for the Cinderella kind of complex.

As long as that choice point stays at 12, 13 years of age, then we are going to have people making wrong decisions and then regretting them.

Mr. **Fuqua**. And that is going to be difficult to change. I know, at that age, with my own self and my own children, they have a lot of different ideas than what they have after they grow up.

Dr. **Berryman**. That is one of the reasons I recommended that we convert what are now electives in the high school to requirements, because what we see is very talented, bright young women, at the age of 14, they manage to winnow out of those courses. They take algebra I, they take geometry I, and then they are through as far as they are concerned. They then have really closed down their options, and they may find when they are in college that, gee, they suddenly want to change, but they cannot any more. It is very, very difficult.

Mr. **Fuqua**. It was revealed in hearings before this committee on the science and math education bill back in 1983 that—I forgot the percentage, but it was a very high percentage, I think it was around 70 percent—maybe some of the staff can correct me—that students beyond the 10th grade took no math or science. They did the minimum amount and that was it.

Dr. **Berryman**. In fact, a lot of your schools don't even offer some of the advanced mathematics courses.

Mr. **Fuqua**. Well, it gets to the chicken-and-egg situation. We are strapped, school systems are strapped, because they have a large number of people that are not certified in those areas that are having to teach those courses, and I imagine that they do not make it as attractive to students to stay in those courses as probably someone more qualified to teach. So we have a very serious problem.

Are there any programs or any disciplines that are successful today for minorities and women?

Mr. **Watson**. Well, sure. In terms of disciplines, I feel that there are a number of disciplines. I also feel that there are a number of students who have lacked the requisite skills in math and science who have gone on to special programs and have been very successful. We have seen dramatic increases——

Mr. **Fuqua**. A remedial program?

Mr. **Watson**. Yes; we have seen dramatic increases in SAT scores, and students have been able to go on to college and complete and become very successful.

Some of the programs—I was reading through some of the literature from the National Science Foundation, in fact, and there is a program in one of the universities out in California that had some very, very good results.

Obviously, it is going to require a cost to duplicate that kind of program across the country, but I think that we have the successes and we know that students can learn and can correct some of those deficiencies if they have the wherewithal, if they have the instruction and the materials and those kinds of things.

So we have some history and some successes if we could only build on that and expand it across the country.

Dr. MALCOM. I would like to agree with Mr. Watson's comment. We do have some fantastic successes, many of them coming out of the Minorities in Engineering Program, which I think has been a testing ground, if you will, for some of the teaching methods, materials, and what have you, ways of dealing with the issue.

I think, also, that the influx, the increased number of women who have gone into engineering over the past 10 years, has been nothing short of phenomenal. I cannot help but believe that this is partly related to the fact that they began to become aware of career options, but it is also related to the fact that they have been told that they must take mathematics or they foreclose their options, and we have seen dramatic increases in the percentage of young women who have persisted and taken more mathematics. We are starting to see some fall-away from those differences, except at the highest levels in high schools.

If you remember, the National Science Foundation had some programs on women in science, career day kinds of things that told them just the kinds of things that we say that they need to hear, and that is what their options are, and second, the importance of persisting with science and mathematics.

Those programs do not exist any more in that form, so where are they to get the information? There are some efforts that have been privately funded. There is a piece here and a piece there. But the problem is there is no coherence to all of these efforts. They are just happening without being able to learn from each other.

There are gaps in funding. There are gaps in programs. I think that this is the thing that is lacking, the coherence and the commitment to support a plan rather than just a piece here and a piece there.

Mr. FUQUA. Thank you very much. We appreciate your being here, Dr. Malcom, Mr. Watson, and Dr. Berryman. We thank you very much for your contributions this morning. They have been very enlightening and helpful. I wish there were a simple answer. [Laughter.]

PANEL 2

Our next panel will be Ms. Betty Vetter, executive director of the Scientific Manpower Commission, and Dr. David Reyes-Guerra, Accreditation Board for Engineering and Technology.

Ms. Vetter, we will be pleased to hear from you.

STATEMENT OF BETTY M. VETTER, EXECUTIVE DIRECTOR, SCIENTIFIC MANPOWER COMMISSION, WASHINGTON, DC

Ms. VETTER. Thank you. I appreciate the opportunity to be able to talk to you this morning to discuss the accuracy and the usefulness of the available data on science and engineering manpower and its ability to predict future needs.

It can be summarized in a sentence: most of the available data are roughly accurate; they are rarely detailed enough for most purposes; they are always too old; they are often too infrequent; and they are never sufficient by themselves to predict future needs accurately. But I would like to expand just a little on each of those.

The accuracy varies from very accurate, such as the degree data that we get from the National Center for Education Statistics and the National Research Council, to roughly reasonable, at least, which is what we have with the estimates for manpower numbers and characteristics data that the National Science Foundation provides.

The NSF data on the characteristics of scientists and engineers aren't really data; they are estimates derived from a series of surveys, each of them sent to relatively small samples of a particular population, each covering different population groups, different timeframes, and each having different response rates. The data from the surveys are then tacked together with some varying weighting procedures to try to estimate how many scientists and engineers there are, whether they are in the labor force, and their various demographic education and employment characteristics. These estimates are made only every other year so that many interim changes also are missed. Even more important, the estimating system is cumbersome and slow to provide results. The data on the numbers of U.S. scientists and engineers in 1982 became available in December 1984. Because it is a biennial compilation, the data on last year's scientists and engineers will be available to us late next year or the year after. The technological marketplace changes far more rapidly than the data are provided, so that short-term changes can rarely be anticipated from this data base, and the long-term changes are subject to a number of other projection problems.

The degree data from both NCES and NRC are very accurate, but they are no more current. The latest, most current available data on degrees from the National Center for Education Statistics is for the 1981-82 school year. We do have the 1982-83 doctoral degrees from the National Research Council.

In addition to these major data sources, many other groups provide data that is either more generalized, such as the Bureau of Labor Statistics, or more specialized, either to a particular field such as chemistry or electrical engineering, or for a single characteristic, such as salaries of one or more groups.

Last year, with funding from the National Science Foundation, the Scientific Manpower Commission published a book called *A Guide to Data on Scientists and Engineers.* It covers all the available data for the years 1972 to 1982, and it includes all studies and series of studies that came from 47 different publishers of data on scientists and engineers. We also prepare an annual summary of the data themselves, which are also subdivided for sex and minority status, so that it is both a manpower book and a book to be used to examine the subject you have just been listening to.

The data from the professional societies is almost always more current than is any of the Government data, but it usually covers only one segment of science or engineering manpower.

Because of differences in methodology and response rates and survey dates and other factors, the data from one source rarely matches or can be combined with data from another. Nonetheless, all of these data sources are useful and used, and they are used for enlarging our understanding of U.S. technological manpower.

One of the functions of the Scientific Manpower Commission is to consider all of the data available and then to prepare and disseminate analytical studies in such areas as supply and demand for scientists and engineers which are geared to the needs of students or of employers or of policymakers or sometimes, hopefully, all three.

I brought two recent examples. One is a chartbook called *Opportunities in Science and Engineering,* with a particular emphasis on trying to attract young women. The other is a new one looking at supply and demand for scientists and engineers and what we know about it and don't know called *The Technological Marketplace.*

Although several of the professional societies do provide various kinds of statistical information on their own members or on their own profession, many others do not. For these, including such very large areas as the biological sciences or, indeed, all the life sciences, the alternate or supplementary data sources to that provided by NSF simply do not exist.

Because the NSF data do not provide detail by subfields such as geology or microbiology or biochemistry, then in those areas where somebody else isn't doing anything, few data of any kind are available.

I said that the available data are rarely detailed enough to provide an accurate picture in sharp focus. The aggregated statistics mask a multitude of differences within each of the larger populations. These differences are vital to an understanding of such questions as how and where to intervene if we want to increase the proportion of minority or female scientists, or whether and when to assist those who have been forced out of their fields by oversupply through changing conditions. The statistical aggregation also leads to erroneous conclusions, frequently.

Although the available data are not detailed enough, they are rarely current, they are updated too infrequently in some cases, and they are only roughly accurate, these are still not probably the most significant reasons why they don't accurately predict the future. Forecasts usually are wrong because too many other factors also affect the outcome.

Previous projections, for example, by both NSF and BLS have not correctly anticipated Federal funding for various activities that have high-technological content. They have not correctly anticipated the students' reaction to their view of future technological demand, which is usually based on the present, no matter when that decision is made, usually 4 to 8 years before they actually enter the marketplace.

Nor have any of these forecasts foreseen the extent of other societal changes such as the women's movement, which I use in its broadest sense, which have shifted all previous patterns of enrollments and career choices. So the forecasts would still be imperfect even if we had better data, although at least some of them would surely be a good deal closer to the mark than they are now.

But, nonetheless, we do need more accurate, more frequent, and more current data than we now have. And we also need data where none now exist in order to provide a basis for making decisions.

The needs for data include detailed, frequent and current data on unemployment rates by field; data on the qualifications of present high school science and math teachers; data on the immigration of foreign scientists and engineers, both those trained here and elsewhere; data on the numbers and proportions of foreign nationals among our faculty members, our teaching assistants, our research assistants, particularly in engineering and in computer science.

We need data on the taxpayer costs of higher education, including the extent of taxpayer support to educate foreign scientists and engineers. This is not to suggest that such data would result in changes in our present system for admitting, supporting, or even utilizing foreign graduates. But the present policies have been made in a data vacuum. They almost surely do not represent the policies that would have been established if such data had been available.

We need data for other vital cost-benefit studies, including the costs for educating more scientists and engineers than we are able to utilize. I have suggested a number of other data needs in the larger paper and some of their uses.

Data collection and analysis and dissemination costs money. The better the data, the more detailed the data, the more money it costs. The real question is whether the expenditure is cost-effective in providing essential information for making informed decisions. I think it almost always is, and I will be happy to answer any questions.

[The prepared statement of Ms. Vetter follows:]

**SCIENTIFIC
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STATEMENT

before the

SCIENCE POLICY TASK FORCE OF THE COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

by
Betty M. Vetter, Executive Director
Scientific Manpower Commission

July 24, 1985

I appreciate the opportunity to appear before you in your study of the supply and demand for scientists and engineers, to discuss the accuracy and usefulness of available data on science and engineering manpower, and its ability to predict future needs.

To summarize first: most of available data are roughly accurate, rarely detailed enough for most purposes, always too old, often too infrequent, and never sufficient to predict future needs accurately. I'd like to expand a little on each of these points.

The bulk of the data on total U.S. scientists and engineers comes from two government agencies: the National Center for Education Statistics, (NCES) which provides data on degrees awarded by U.S. colleges and universities; and the National Science Foundation which supplies data on graduate enrollments and on the labor force. In addition, many other groups provide data that is either more generalized - e.g. the Bureau of Labor Statistics; or more specialized, either for a particular field, such as chemistry or electrical engineering; or by a characteristic such as salaries, for one or more fields. Last year, the Scientific Manpower Commission published a **Guide to Data on Scientists and Engineers,** covering all available data for the years 1974-1982, which includes studies and series of studies from 47 different groups. We also prepare annual compilations of the data themselves, from all sources, with each of the tables delineated by sex and/or minority status, published under the name, **Professional Women and Minorities: A Manpower Data Resource Service.**

The degree data from NCES are quite accurate, because they are based on a total sample of all institutions awarding degrees, with a very high response rate. NSF data on the labor force in science and engineering and

American Association for the
  Advancement of Science
American Astronomical Society
American Chemical Society
American Geological Institute
American Geophysical Union
American Institute of Biological Sciences
American Institute of Chemists
American Institute of Physics
American Meteorological Society
American Nuclear Society
American Psychological Association
Association for Computing Machinery
Federation of American Societies
  for Experimental Biology
National Science Teachers Association
Society for Industrial and Applied
  Mathematics

its characteristics - age, sex, race, field, highest degree, employment sector, major activity, salary, etc. - are not really data, but estimates derived from a series of surveys - each sent to relatively small samples of a particular population; each covering different population groups and different time frames, and each having different response rates. Data from these surveys are then tacked together with varying weighting procedures to try to estimate how many scientists and engineers there are, whether or not they are in the labor force, and their various demographic, educational and employment characteristics.

Data usually result from a survey, which is a snapshot taken at a particular moment in time, with the camera focused on a particular population, or on a sample of that population. If snapshots are taken frequently, it is easier to plot a curve from the changes observed, and such curves help to forecast future changes. However, when the snapshots are too far apart in time, it is not always possible to understand the observed changes well enough to anticipate future changes. This difficulty is compounded when copies of the snapshot are not available for viewing within a short time, and is further compounded when it is one of several snapshots taken of different groups at different times and then melded together into a composite drawing.

At least in part because this estimating system is so cumbersome, it also is slow to provide results. Data on the number and characteristics of U.S. scientists and engineers in 1982 finally was issued at the end of 1984. Since this compilation is done only every other year, we can expect the next information (on last year's science and engineering population) to be available in late 1986 or early 1987. Although some estimates for 1983 will be made in the interim, the technological marketplace changes far more rapidly than data are provided, so that short term changes can rarely be predicted from this data base, and long term changes are subject to other projection problems. Some effort is made to monitor some of these changes between major surveys, but these, too, result only in rough estimates.

Of course, NSF also provides data on other aspects of the economy that affect the supply and utilization of scientists and engineers - such as R&D budgets and expenditures, graduate enrollments, and academic employment.

The degree data from NCES is comprehensive and accurate, but no more current. The latest degree data available in July 1985 is for the 1981-82 academic year.

Data from other sources, such as the professional societies in science and engineering, is almost always more current, but most data from these sources covers only one segment of science and engineering manpower. Because of differences in methodology, response rates, survey dates and other factors, data from one source rarely matches data from another source. However, all of these data sources are useful for enlarging our understanding of U.S. technological manpower. One of the functions of the Scientific Manpower Commission is to consider all of the data available, and to prepare analytical studies in such areas as supply and demand for scientists and engineers, geared to the needs of students, employers or policy makers.*

Along with everybody else, we rely on the Engineering Manpower Commission, for example, to provide timely enrollment and degree data in engineering. Similar information in physics is provided by the American Institute of Physics. Some professional societies provide various kinds of statistical information on their own members, including the American Chemical Society, the Institute for Electrical and Electronic Engineers, the American Psychological Association and a few others. However, for most fields, including some of the largest, such as the biological sciences, alternate or supplementary data sources do not exist.

For those fields where NSF data do not provide any breakout (such as geology or microbiology) few data are available anywhere.

I noted that the available data are rarely detailed enough to provide an accurate picture in sharp focus. This is because sample surveys almost never include a large enough sample to provide reliable data on small groups. Thus, NSF provides estimates for both numbers and characteristics of biological scientists in the aggregate, but no detail at all for cell biologists or microbiologists or botanists. NSF data on environmental scientists include, but do not differentiate, geologists. There are no subfield breakouts for chemistry or physics. Systems analysts, programmers and other specialists in the rapidly emerging field of computers are aggregated together as computer specialists. The lack of detail applies not only to smaller fields or subfields, but also to small groups within larger populations such as black women in computer specialties, or Hispanic chemical engineers. The aggregated statistics mask a multitude of differences within each of the larger populations, some of them vital to an understanding of such questions as how and where to intervene to increase the proportion of female or minority participants; or whether and when to assist those forced into career changes by changing conditions. Statistical aggregation also leads to erroneous conclusions. A general undersupply of computer specialists or an oversupply of biologists tells us little about the large differences in supply and demand balance in the subsets of these large groups.

Although the available data are not detailed enough, are rarely current, and are only roughly accurate, these are not the only or even the most significant reasons that we cannot predict future needs with some confidence. Even with a completely comprehensive and current database, none of us who try to assess future supply or future demand, or the balances or imbalances between them would be wholly successful, although the degree of success almost surely would rise with better and more current statistics. The reason that forecasts usually are wrong is that too many other factors also affect the outcome. To account for this, some forecasts are made under different scenarios that use various assumptions about the economy, federal budgets, etc.

To understand one of the biggest problems in forecasting future demand, we must differentiate between "demand" and "need", and the difference is money. No matter how many scientists or engineers may be needed to carry out national endeavors, none can be hired unless funds are available to pay them. Neither forecasters nor students preparing for careers, nor the institutions that train them can always anticipate the priorities that will govern these funding decisions by future administrations and future congresses. The employment of scientists and engineers, more than most other occupational groups, is highly sensitive to federal expenditures in areas with a high technological component.

Previous projections have not correctly anticipated student reactions to their view of future technological demand, or to other societal factors such as the women's movement, which have changed previous patterns of enrollments and career choices.

Thus, even if the available data were better than they are, forecasts would still be imperfect, although at least some of them surely would be closer to the mark than in the past. Nonetheless, we need more accurate, more frequent, and more current data than we now have, and we particularly need data where none now exist, in order to provide a basis for decision making by the Congress and others.

Let me give you a few examples. One of the best ways to determine whether supply and demand are out of balance is to look at unemployment rates. Both when the economy is growing and when it is not, national unemployment rates are reported once each month, with some breakouts for particular groups, such as black teenage males. However, the unemployment rate for biologists, for example, is estimated only once every two years. Not only are significant changes likely to occur during such a long period, but in addition, that rate may be relatively high for the group as a whole, while at the same time there may be a severe nationwide shortage of Ph.D. physiologists or some other specialized subfields. Students preparing for a career in some specialty of the biological sciences may be discouraged by relatively high unemployment rates indicated by the only information available, and may drop out, when instead they should have been able to learn which specialties are overcrowded and which are understaffed, so that they might make **informed** decisions. Presently, there are no data to help provide that information.

- Despite the national concern with the quality of science and math education at the elementary and secondary levels, we have no data on the qualifications of present high school science and math teachers.

- We also have faculty problems at the college level. Despite significant surpluses of potential faculty in some fields, we have serious shortages in others - particularly in electrical/electronic engineering and computer science. Although we have data on authorized but unfilled faculty positions in engineering, we know very little about the composition of current faculty. As you know, for the past several years, less than half of our doctoral graduates in engineering have been U.S. citizens. Foreign nationals are an increasing, but unknown proportion of faculty, of teaching assistants, and of research assistants in engineering and computer science. Many do not have the command of English needed for teaching U.S. students.

- We need accurate and current data on the immigration of foreign scientists and engineers - both those who were educated in their own countries, and those who first entered the U.S. as students, and completed their graduate education here, later changing their status to permanent immigrant and, in many cases, to naturalized citizen.

- We need data on the extent to which U.S. taxpayers support the education of foreign engineers and scientists. This is not to suggest that such data would or should result in changes in our present systems for admitting, supporting, or even utilizing foreign graduates; but to quote a new report from the National Academy of Sciences, "The problem is that we really do not know anything concrete about the costs and benefits involved because the basic statistics are so limited. Policy has been made in a data vacuum that should naturally be abhorred by policy makers." The Academy report points out that a statistical system to produce immigration data does exist, but it does so in an atmosphere of almost total neglect. The Scientific Manpower Commission recently sponsored a symposium on the education and utilization of foreign scientists and engineers. The Congress will again be looking at immigration reform, including policies for re-admitting or retaining foreign graduates from U.S. Universities. Unless some action is taken to provide essential statistics, decisions will continue to be made in a data vacuum.

- Better data on the costs (particularly taxpayer-supported costs) of U.S. higher education also are needed for other vital cost/benefit studies. What is the cost of paying to educate to the doctoral level persons who cannot find employment related to that education? Who pays it? If we encourage more and more students to enter aeronautical engineering because the job outlook in that field is enhanced by high defense budgets, and then a new administration changes that policy and reduces those budgets, thereby throwing these aeronautical engineers out of work, for example, what is this cost, both in monetary and human terms? Is there a better way to provide more accurate planning information for students and their training institutions?

- We are not sure of the amount of oversupply already existing in some science fields. One set of data that would help us to answer part of that question would be characteristics of the current postdoctorates, including the number of years they have spent in postdoctoral positions. To some unknown extent, postdoctoral positions have become holding tanks for surplus Ph.D.s. NSF provides data on the number of postdoctorates in academic institutions, but nothing about their tenure in these slots. How cost-effective is this practice of multiple year postdoctorates, and who benefits from it? We need continued field-by-field tracking of both labor market and scientific outcomes for recent cohorts of Ph.D.s, with and without postdoctoral experience.

The real question of cost is, of course, if not this, then what? If, instead of allocating present proportions of taxpayer income to pay for defense (including the training of more aeronautical engineers), those taxes were used to rebuild the nation's infrastructure (so we'd need to pay for civil engineers instead) or not levied at all, so that workers could invest in education, retirement funds, or whatever they chose, does the nation gain or lose? We can't even do the modeling to find out without knowing what that cost is and who pays it now. If the current R&D budget from all sources were redistributed so that far more went to basic research, for instance, or to non-defense development, or to something quite different than it does now, what are the tradeoffs we might hope for in our balance of trade or in other areas? Knowing the relative cost of one thing vs. another should make it easier for legislators to budget, as it surely does for families and other smaller units.

* Another data need is for accurate and timely trend data on all segments of the education/utilization pipeline in science and engineering, with the data broken out by sex and minority status. As others will testify in these hearings, most projections through the mid 1990s indicate no significant shortages of scientists and engineers (except perhaps aeronautical engineers and computer specialists). But with a declining college-age population, it will be more difficult to maintain high quality if we continue to allow present barriers to affect the recruitment, education and utilization of women and members of minority groups. Many studies find the barriers continuing. But most available data allow us to examine only the outcomes rather than the barriers along that pipeline.

These are some of the reasons why we need more data, more accurate and detailed data, and more current data. We could not then be certain of our ability to forecast the future, but we could feel more confident that decisions which must be made take into consideration the most accurate information obtainable.

Data collection, analysis and dissemination costs money. The more accurate and detailed the data, the higher the cost. The real question is whether that expenditure is cost-effective in providing essential information for making informed decisions. I believe that it almost always is.

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*Two recent examples are: **Opportunities in Science and Engineering: A Chartbook Presentation** by Betty M. Vetter, (Scientific Manpower Commission, November 1984); and **The Technological Marketplace: Supply and Demand for Scientists and Engineers** by Betty M. Vetter, (Scientific Manpower Commission, May 1985).

Mr. FUQUA. Thank you very much.
Dr. Reyes-Guerra.

STATEMENT OF DR. DAVID R. REYES-GUERRA, EXECUTIVE DIRECTOR, ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY [ABET], NEW YORK, NY, ACCOMPANIED BY DR. GENE NORDBY, PRESIDENT, ABET

Dr. REYES-GUERRA. Thank you, Mr. Chairman.

I am David Reyes-Guerra, the executive director of the Accreditation Board for Engineering and Technology, and I am privileged today to be accompanied by the incoming president of ABET, Dr. Gene Nordby, who just terminated his term as chancellor of the University of Colorado at Denver, and he will follow my remarks with some remarks of his own.

ABET is the one and only federation of engineering societies fully dedicated to covering the total aspect of engineering education through its 21 societies representing nearly 1 million engineers.

I have accompanied some charts that you might want to refer to as I go through my presentation.

This marks the first time that ABET officially has been invited and has presented evidence or testimony before a congressional committee, and we are very proud about that opportunity. I think it is about time that ABET did bring its knowledge to the presence of committees such as yours.

Among the various aspects of activity, we are best known for the accreditation function, the means by which the profession determines which college program in an individual engineering discipline has met the minimum requirements of the profession. ABET covers the entire gamut of the spectrum of the profession—engineering, engineering technology and the related fields at the associate, baccalaureate, and advanced level.

Through its society membership, ABET sets the criteria or standards that are applied to the educational programs, taking into account all those items that are common to all engineers as well as those necessary for each individual discipline.

ABET is deeply involved in all aspects of education to ensure that the accreditation criteria is adequate and corresponds to the state of the art of the profession. The responsibility for maintaining the strength of engineering education at a competitive level with the rest of the world as well as on the frontiers of new discoveries is part of the vision for all of those in ABET. Most of the major studies in engineering education have either been initiated through ABET or have had significant ABET input.

Since its founding in 1932, ABET has collected the necessary data to carry out its accreditation function. This data is one of the means by which the compliance of the individual program is determined with regard to ABET criteria.

The ABET data is the only data that is verified by a team of professionals, as each accreditation action requires a campus and program visit where the facts as stated in the data are verified. Unfortunately, ABET has not had the necessary outside support in order to publish or analyze in depth its data. This hearing is the first instance in which some of the ABET data is presented to the general public.

The data I am referring to covers the highlights of engineering programs only. Comparable data is available for engineering technology and the related fields. The data is gathered from a total population of 259 institutions offering a total of 1,321 specialized programs, 1,267 at the bachelor's level and 54 at the master's level. From chart B, you will note that each year ABET averages visits to approximately one-third of all institutions and the same approximate ratio of programs. I will submit a new chart B for the record simply because, in the word processing, they forgot the 1984 and 1985 figures. The 1984 and 1985 figures are 327 actions each year; in the universities, in 1984 and 1985, they are 77 for 1984 and 90 for 1985. The yearly ABET data, though not representative of the same institution or program on a yearly basis, is representative of the total population and can safely be taken as representing what is occurring in the profession.

CHART B

ENGINEERING ACCREDITATION ACTIONS

1978 - 1985

YEAR	ACTIONS	UNIVERSITIES
1978	280	62
1979	283	73
1980	151	43
1981	241	57
1982	308	67
1983	353	88
1984	327	77
1985	327	90

Each action represents one program which was submitted for accreditation or reaccreditation at a college or university, e.g. Mechanical Engineering, Computer Engineering, etc.

TERMS OF ACCREDITATION

6V =6 years

3R =3 years, with a report due before then. Acceptance of the report by ABET extends the term by another 3 years.

3V =3 Years

SC =Show cause why accreditation should not be terminated.

NA =Not accredited.

In connection with your area of interest, our summary of accreditation actions in engineering is clearly shown in graphical form under chart C, and I refer you to chart C, which is a complicated chart, but I think we can explain it. Note especially that there is a consistent number of programs that do not meet the accreditation criteria—that is, not to accredit, "NA"—as well as some previously accredited programs which are found to be so deficient that they will have their accreditation terminated within a 3-year period unless drastic changes are made to bring them into compliance. They have the "SC" label, which means show cause. These two categories together can be considered as failure rates and comprise from 11 to 16 percent of the total submitted for accreditation each year.

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ENGINEERING ACCREDITATION ACTIONS

1979 THRU 1985

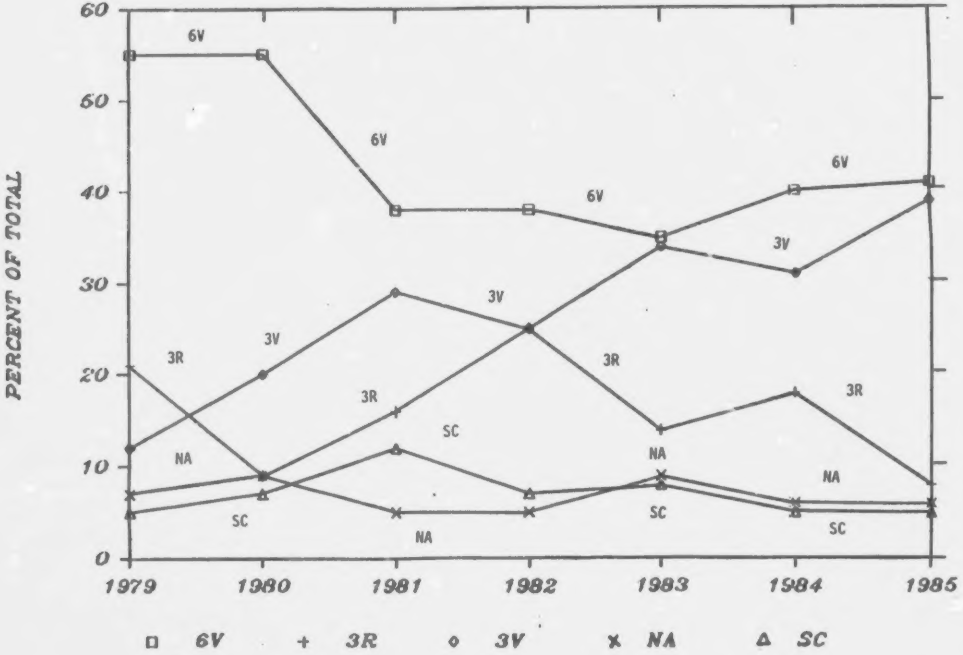

CHART C

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Programs which have minor violations of criteria are placed on report action; that is, "3R." This category can be considered to be one of the most favorable. Once the program deficiency is corrected, a report on the correction, if accepted by ABET, is sufficient to extend the accreditation from 3 years to the maximum of 6 years. Note that 3R has changed from slightly less than 10 percent to a maximum of approximately 25 percent of total actions.

The most important curves in chart C are those labeled "6V" and "3V;" 6V means the maximum term of accreditation, 6 years, and is given to those programs that meet the minimum ABET criteria. 3V is given to programs that have serious deficiencies whose correction can only be determined after an on-site campus visit in 3 years.

You will note that in 1979-80, 6V actions were at a 55-percent level. Coincident with the cry in the profession of quality deficiency, the 1981 accreditation actions of 6V confirmed the deficiency by reaching a low of approximately 38 percent, which again in 1983 dropped a few more percentage points to an all-time low. The recovery has been slow for 1984 and 1985, clearly showing how difficult it is for the institutions to institute corrective actions, not because of lack of effort on their part to improve the quality of their offerings but simply, in my opinion, because many of the elements necessary for corrections are not available in the marketplace, especially faculty. With the unprecedented growth of interest in engineering education—almost a threefold increase in undergraduate students in 10 years—a comparable increase in available graduate students has not materialized. Note that for the 1985 year the 6V level of accreditation is less than 2 percent higher than that in 1984.

The 3V curve, in 1979 at a low of approximately 12 percent, has consistently increased as the problem of maintaining quality in engineering education exacerbates. Thus, now, in 1985, it is approximately at the same level as the 6V actions.

I thank the chairman for scheduling the meeting at this time because this has allowed me to bring you the data that was just released last week at a meeting in Kansas City of the accreditation commissioners.

The above description should be sufficient to portray the reality of the serious deficiency in quality engineering education. When a large portion of the programs submitted for accreditation at a minimum level are unable to acquire the maximum term offered, there is definitely a problem in the system.

Chart D, which is taken from the data of the Engineering Manpower Commission, points out quite vividly the large change in the population seeking an engineering education.

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HISTORICAL SUMMARY
ENGINEERING ENROLLMENTS IN FALL, 1984
As Compared With Earlier Years

CHART D

	Fall 1973	Fall 1974	Fall 1975	Fall 1976	Fall 1977	Fall 1978	Fall 1979	Fall 1980	Fall 1981	Fall 1982	Fall 1983	Fall 1984
Engineering Students												
Freshman Year, Full-Time	51,925	63,444	75,343	82,250	88,780	95,805	103,724	110,149	115,280	115,303	109,638	104,629
Sophomore Year, Full-Time	40,519	45,935	55,891	63,003	70,326	72,150	78,594	84,982	87,519	89,785	89,515	83,326
Junior Year, Full-Time	41,673	43,007	94,338	56,835	64,721	69,816	74,928	80,024	86,633	90,541	91,233	89,099
Senior Year, Full-Time	48,366	44,538	47,070	51,692	60,109	68,260	77,823	84,442	92,414	102,055	109,036	109,285
Fifth Year, Full-Time	4,222	4,175	3,737	4,055	5,312	5,206	5,419	5,520	5,731	5,706	6,722	6,236
TOTAL FULL-TIME UNDERGRAD	186,705	201,099	231,379	257,835	289,248	311,237	340,488	365,117	387,577	403,390	406,144	392,575
Part-Time Undergraduates	15,692	16,689	17,041	19,844	20,634	22,843	25,811	32,227	32,825	31,940	35,061	34,504
Master's Degree, Full-Time*	22,588	21,999	26,004	25,516	26,876	26,060	27,923	29,870	32,310	33,968	38,826	37,538
Doctorate, Full-Time	11,904	10,628	11,281	10,963	12,359	12,321	13,461	14,465	15,472	16,442	18,540	19,459
TOTAL FULL-TIME GRADUATE STUDENTS	34,492	32,627	37,285	36,379	39,235	38,381	41,384	44,335	47,772	50,410	57,366	56,997
Part-Time Grad. Students	26,114	27,572	27,173	26,842	25,065	24,133	25,768	28,250	29,818	31,589	33,674	35,058
Number of Schools	285	282	291	289	289	276	286	287	286	286	292	----
Number of schools with at least one curriculum accredited by ABET	**	**	**	**	**	**	239	246	250	249	258	----

* Includes Engineer Professional Degrees

** Not available prior to 1979

E.M.C. Data July 1985

Chart E gives a summary of the criteria areas covered by ABET. Note that all the issues that effect education are included in the criteria, including the curricular subject matter required by engineering. The curricular content that is prescribed covers 3 years of a 4-year college baccalaureate program. Though the fourth year is not prescribed, it is expected that it will be used to complete, and I quote, "an integrated experience aimed at preparing the graduate to function as an engineer." We believe that the average engineering student accumulates a total of 136 semester credit hours by graduation starting with calculus as the first course in the mathematics area. This compares to 120 semester credit hours required by a liberal arts and sciences baccalaureate with an entry point to mathematics of college algebra, which is two or three courses below the engineering student. The difference between 136 and 120 then becomes closer to 146 to 120 for a baccalaureate.

CHART E

ENGINEERING ACCREDITATION

CRITERIA AREAS

GENERAL/PROGRAM

1. Faculty
2. Curricular Objective and Content
    - A. One Year of an Appropriate Combination of Mathematics and Basic Sciences
    - B. One Year of Engineering Sciences
    - C. One Half-Year of Engineering Design
    - D. One Half-Year of Humanities and Social Sciences
3. Student Body
4. Administration
5. Institutional Facilities
6. Institutional Commitment

Additional/Different Criteria Exist for:

1. Non-Traditional Programs
2. Innovative and Experimental Programs
3. Cooperative Education

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Chart F provides you with a summary of the reasons cited by ABET for a specific program failing to obtain less than maximum term accreditation; that is, 6V. Note that curriculum deficiencies are showing up as the most significant, followed by faculty—which undoubtedly relates to curriculum—and by laboratories. Note also that the laboratory issue has been addressed by the institutions and shows major improvement. This shows that corrective actions on equipment—inanimate objects—can be instituted by budgetary controls. However, intellectual property—namely faculty and curricula—cannot be purchased but must be developed, and that takes time and people with the right motivation and ability as administrators, teachers, and students.

CHART F

REASONS FOR LESS-THAN-MAXIMUM ENGINEERING ACCREDITATION ACTIONS

AREA OF CONCERN	1982-83 No.	1982-83 %	1983-84 No.	1983-84 %	1984-85 No.	1984-85 %
Faculty	94	19%	104	24%	63	15%
Curriculum	147	30%	130	30%	169	40%
Advising	32	7%	33	8%	42	10%
Laboratories/Equipment	127	26%	108	25%	71	17%
Administration	37	8%	42	10%	34	8%
Low Enrollment	6	1%	2	-	14	3%
Resources Allocation	41	8%	15	3%	34	8%
Deficiencies Cited	484		434		427	
Programs Reviewed	230		186		183	

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Chart G compares accreditation deficiencies as related to each term of accreditation for the 1985 academic year. As could be expected, the higher ratio of deficiencies per program corresponds to the most restrictive action.

CHART G

BREAKDOWN OF REASONS FOR LESS-THAN-MAXIMUM
ENGINEERING ACCREDITATION ACTIONS
1984-85

AREA OF CONCERN	3R	3V	SC	NA	TOTAL
Faculty	6	42	9	6	63
Curriculum	14	104	32	19	169
Basic Science/Math	(0)	(9)	(5)	(2)	(16)
Engineering Science	(0)	(5)	(3)	(2)	(10)
Design	(4)	(44)	(16)	(7)	(71)
Humanities	(3)	(7)	(3)	(3)	(16)
Other	(7)	(39)	(5)	(5)	(56)
Advising	11	26	2	3	42
Laboratories/Equipment	9	54	7	1	71
Administration	4	24	3	3	34
Low Enrollment	1	10	1	2	14
Resources Allocation	1	31	2	0	34
Total Deficiencies Cited	46	291	56	34	427
Programs Reviewed	26	124	20	13	183
Deficiencies per Program	1.77	2.35	2.80	2.62	2.33

To obtain data on individual items that affect the quality of programs, ABET has prepared a compendium of data covering essential findings at each institution and comparing the summary for the 1982 to 1985 years. Chart H shows this data and gives ratios between the 1985 and 1982 data. You will note that the institutions are trying to respond to pressures by mobilizing their resources in support of engineering. However, in spite of the effort made to date, some items such as the student-faculty ratio have not improved over the past 4 years.

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

ENGINEERING COLLEGE AS A WHOLE ALL INSTITUTIONS

CHART H

	ACADEMIC YEARS				
ITEM*	1982	1983	1984	1985	1985/1982 RATIOS
ENTIRE INSTITUTION					
Student/Faculty	15.64	16.65	15.44	15.17	.97
Tot. Educ. Exp./Faculty	$115,698	$118,661	$148,348	$144,940	1.25
Tot. Educ. Exp./Student	$ 8,046	$ 7,768	$ 12,398	$ 9,554	1.19
ENGINEERING COLLEGE					
U.G. Student/Faculty	24.58	22.29	18.79	20.33	.83
Support Pers./Faculty	.43	.4	.41	.47	1.09
Oper. Exp./Faculty	$ 7,663	$ 5,833	$ 11,059	$ 8,028	1.05
Oper. Exp./U.G. Student	$ 567	$ 487	$ 1,708	$ 395	.70
Capital Exp./Faculty	$ 4,825	$ 8,151	$ 9,210	$ 11,120	2.30
Travel Exp./F/T Faculty	$ 608	$ 1,075	$ 777	$ 891	1.47
Computer Exp./U.G. Student	$ 171	$ 417	$ 1,145	$ 286	1.67
B.S. Degrees/Faculty	3.9	4.01	5.54	3.79	.97
Degree Productivity Index**	5.35	5.42	7.66	5.95	1.11
High Salary-Professor	$ 43,616	$ 55,422	$ 52,927	$ 54,204	1.24
Mean Salary-Professor	$ 34,862	$ 38,077	$ 41,522	$ 43,069	1.24
Low Salary-Professor	$ 28,336	$ 29,891	$ 33,021	$ 34,760	1.23
High Salary-Assoc. Prof.	$ 31,665	$ 35,259	$ 37,915	$ 38,601	1.22
Mean Salary-Assoc. Prof.	$ 27,369	$ 30,407	$ 32,613	$ 33,928	1.24
Low Salary-Assoc. Prof.	$ 23,591	$ 25,319	$ 27,823	$ 29,118	1.23
High Salary-Asst. Prof.	$ 26,613	$ 29,187	$ 31,356	$ 33,075	1.24
Mean Salary-Asst. Prof.	$ 23,688	$ 26,204	$ 28,227	$ 29,369	1.24
Low Salary-Asst. Prof.	$ 21,087	$ 23,093	$ 23,885	& 25,597	1.21
TOTAL NUMBER OF INSTITUTIONS	83	65	86	77	

* Students (undergraduates) and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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The salary data that we present is in terms of a 9-month academic year.

Charts I, J, and K show the same compilation of questions as shown on chart H, the total of the engineering colleges, but broken down for some selected disciplines. In this case the data is presented for electrical engineering, mechanical engineering, and civil engineering. These disciplines were selected as being representative of a good cross section of the engineering population.

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

ELECTRICAL ENGINEERING PROGRAMS

CHART I

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	27.8	26.13	20.07	21.95	.78
Support Pers./Faculty	.31	.27	.29	.29	.93
Grad. Assts./Faculty	.61	.76	.49	.54	.88
Oper. Exp./Faculty	$ 3,073	$ 2,611	$ 3,843	$ 5,275	1.71
Capital Exp./Faculty	$ 4,035	$ 8,896	$ 14,331	$ 13,992	3.46
Capital Exp./U.G. Student	$ 166	$ 475	$ 1,395	$ 638	3.84
Travel Exp./F/T Faculty	$ 654	$ 943	$ 1,122	$ 813	1.24
Computer Exp./U.G. Student	$ 119	$ 132	$ 965	$ 248	2.00
B.S. Degrees/Faculty	3.72	4.36	3.66	4.10	1.10
Degree Productivity Index	5.06	6.07	5.85	6.18	1.22
Required Sem. Hrs. for Degree	132.56	132.46	142.61	145.67	1.09
Lab Area/Faculty (Sq. Ft.)	697	690	619	624	.89
Lab Area/U.G. Student(Sq. Ft.)	27	31	215	28	1.03
High Salary-Professor	$ 41,567	$ 46,604	$ 47,291	$ 48,480	1.16
Mean Salary-Professor	$ 35,086	$ 39,348	$ 40,800	$ 42,154	1.20
Low Salary-Professor	$ 30,302	$ 34,025	$ 35,283	$ 37,157	1.22
High Salary-Associate Prof.	$ 30,234	$ 33,683	$ 34,888	$ 36,433	1.20
Mean Salary-Associate Prof.	$ 28,136	$ 30,888	$ 32,568	$ 33,738	1.19
Low Salary-Associate Prof.	$ 26,404	$ 27,846	$ 30,241	$ 31,633	1.19
High Salary-Assistant Prof.	$ 26,472	$ 28,291	$ 29,684	$ 31,454	1.18
Mean Salary-Assistant Prof.	$ 24,954	$ 27,220	$ 28,126	$ 29,877	1.19
Low Salary-Assistant Prof.	$ 23,787	$ 26,032	$ 26,533	$ 27,811	1.16
TOTAL NUMBER OF INSTITUTIONS	52	36	51	49	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

MECHANICAL ENGINEERING PROGRAMS

CHART J

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	23.63	23.48	18.17	17.89	.75
Support Pers./Faculty	.26	.31	.64	.26	1.00
Grad. Assts./Faculty	.38	.58	.51	.54	1.42
Oper. Exp./Faculty	$ 3,217	$ 3,038	$ 3,334	$ 4,140	1.28
Capital Exp./Faculty	$ 2,188	$ 4,950	$ 11,135	$ 8,042	3.67
Capital Exp./U.G. Student	$ 117	$ 297	$ 3,088	$ 449	3.83
Travel Exp./F/T Faculty	$ 644	$ 1,214	$ 1,181	$ 1,917	2.97
Computer Exp./U.G. Student	$ 86	$ 117	$ 1,245	$ 300	3.48
B.S. Degrees/Faculty	3.64	4.47	4.80	3.50	.96
Degree Productivity Index	4.57	5.75	6.49	4.48	.98
Required Sem. Hrs. for Degree	133.13	131.30	140.96	145.30	1.09
Lab Area/Faculty (Sq. Ft.)	982	998	960	983	1.00
Lab Area/U.G. Student(Sq. Ft.)	47	49	451	55	1.17
High Salary-Professor	$ 39,539	$ 46,903	$ 48,741	$ 48,189	1.21
Mean Salary-Professor	$ 34,646	$ 38,849	$ 41,612	$ 41,904	1.20
Low Salary-Professor	$ 30,358	$ 32,738	$ 35,541	$ 37,235	1.22
High Salary-Associate Prof.	$ 29,068	$ 33,616	$ 34,948	$ 36,324	1.24
Mean Salary-Associate Prof.	$ 27,487	$ 31,213	$ 32,533	$ 34,194	1.24
Low Salary-Associate Prof.	$ 25,706	$ 28,848	$ 29,918	$ 31,942	1.24
High Salary-Assistant Prof.	$ 25,282	$ 28,023	$ 30,567	$ 31,354	1.24
Mean Salary-Assistant Prof.	$ 23,879	$ 27,262	$ 28,954	$ 29,519	1.23
Low Salary-Assistant Prof.	$ 22,242	$ 26,526	$ 27,498	$ 28,004	1.25
TOTAL NUMBER OF INSTITUTIONS	45	36	57	50	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{1 \text{ B.S.} + 1.5 \text{ M.S.} + 3.0 \text{ PhD}}{\text{FTE}}$

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

CIVIL ENGINEERING PROGRAMS

CHART K

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	19.26	15.27	13.1	13.3	.69
Support Pers./Faculty	.28	.29	.3	.29	1.03
Grad. Assts./Faculty	.47	.66	.56	.42	.89
Oper. Exp./Faculty	$ 2,444	$ 2,783	$ 3,450	$ 3,227	1.32
Capital Exp./Faculty	$ 2,984	$ 5,734	$ 10,089	$ 6,622	2.21
Capital Exp./U.G. Student	$ 180	$ 409	$ 1,544	$ 498	2.76
Travel Exp./F/T Faculty	$ 734	$ 1,194	$ 10,297	$ 829	1.12
Computer Exp./U.G. Student	$ 101	$ 228	$ 475	$ 261	2.58
B.S. Degrees/Faculty	3.88	3.44	3.65	3.18	.81
Degree Productivity Index	5.38	5.04	5.01	4.62	.85
Required Sem. Hrs. for Degree	133.45	132.32	142.51	144.95	1.08
Lab Area/Faculty (Sq. Ft.)	955	1,113	881	848	.88
Lab Area/U.G. Student(Sq. Ft.)	76	86	116	64	.84
High Salary-Professor	$ 39,520	$ 46,908	$ 47,536	$ 45,960	1.16
Mean Salary-Professor	$ 34,436	$ 39,407	$ 41,213	$ 41,481	1.20
Low Salary-Professor	$ 30,246	$ 33,608	$ 36,769	$ 37,079	1.22
High Salary-Associate Prof.	$ 29,034	$ 33,556	$ 35,188	$ 34,437	1.18
Mean Salary-Associate Prof.	$ 27,112	$ 30,788	$ 32,550	$ 32,465	1.19
Low Salary-Associate Prof.	$ 25,581	$ 28,026	$ 29,736	$ 30,782	1.20
High Salary-Assistant Prof.	$ 25,644	$ 28,522	$ 29,650	$ 29,621	1.15
Mean Salary-Assistant Prof.	$ 23,776	$ 27,243	$ 28,297	$ 28,933	1.21
Low Salary-Assistant Prof.	$ 22,706	$ 26,138	$ 26,764	$ 27,955	1.23
TOTAL NUMBER OF INSTITUTIONS	41	40	46	42	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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Students show a marked interest, by the number of applicants, for electrical engineering. Mechanical engineering at present occupies the median level of interest among students, with civil engineering being among the disciplines which draw less interest from students. This data is presented without comment or analysis. I believe it speaks for itself.

Chart L is an attempt to provide you with a comparison obtained from a representative sampling of the quality of entering students as determined through the standard college admission tests, the Scholastic Aptitude Test and the American Collegiate Test.

SURVEY ON QUALITY OF ENTERING ENGINEERING STUDENTS

	UNDERGRADUATE DATA								GRADUATE DATA
1 Year	2 Approx. # of Students Applying for Admission to Engineering	3 Approx. # Admitted	4 Avg. SAT Composite Score	5 Avg. SAT Math	6 Avg. SAT Verb.	7 Avg. ACT Composite Score	8 Avg. ACT Math	9 Avg. ACT Verb.	10 Average GRE Composite Score
1970	1741.5	800.9	1181.8	614.4	541.6	24.26	27.0	20.78	1193
1975	1562.3	955.0	1129.2	601.0	527.6	23.32	25.86	19.86	1191.3
1980	2519.4	1206.0	1168.6	617.2	536.0	23.54	25.45	20.43	1176.3
1985	2576.9	1172.1	1184.6	632.0	545.2	25.10	27.13	21.89	1162

1970 sample represented 19.0% of engineering freshman population
1975 sample represented 27.9% of engineering freshman population
1980 sample represented 26.3% of engineering freshman population
1985 sample represented 27.1% of engineering freshman population

Survey questionnaire sent to 30 engineering schools out of 258 with ABET-accredited programs. Response was obtained from 24 schools.

CHART L

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You will note that the ratio of students applying for admission and the number admitted has not changed markedly between 1970 and 1985. However, the absolute numbers have increased significantly. Contrary to expectations, the average composite scores of the college tests have not changed appreciably between 1970 and 1985. Of special interest is to note that the average admissions scores hit an all-time low in 1975. Thus, by comparing to the immediate past, especially 1975, it can be said that the quality of the entering students has increased significantly, but compared to 1970, that is not true.

The above material is one way in which ABET wants to contribute to your deliberations. The data speaks for itself. Any analysis will confirm that there is a problem with maintaining quality in engineering education and will support some of the remedial measures suggested at these hearings by representatives from the engineering profession who have preceded us.

A very important issue which is obvious at this time is the need to separate science data from that of engineering. Both groups are different and should not be mixed. When the data is presented in a joint form, the perspective of what each group requires is completely clouded.

ABET is ready to assist in any way it can to help alleviate the problem areas in engineering education. One way we can be effective is by providing you with this verified data.

Thank you for the opportunity, and if you don't mind, Mr. Chairman, I would like to ask Dr. Nordby to give a few remarks.

[The prepared statement of Dr. Reyes-Guerra follows:]

Testimony of

David R. Reyes-Guerra, P.E.

Executive Director

Accreditation Board for Engineering and Technology (ABET)

Before the

Committee on Science and Technology

U.S. House of Representatives - Science Policy Task Force

Room 2318 Rayburn House Office Building

July 24, 1985

Chairman Don Fuqua and members of the committee. I was very pleased to receive an invitation from Chairman Fuqua to appear before you as one of the participants in the hearings on "Scientists and Engineers: Supply and Demand." My name is David R. Reyes-Guerra and I serve as the Executive Director of the Accreditation Board for Engineering and Technology, better known as ABET - the one and only federation of engineering societies fully dedicated to covering the total aspect of engineering education through its 21 societies representing nearly 1,000,000 engineers - (Chart A)

ABET, among its various areas of activity, is best known for the accreditation function. The means by which the profession determines which college program in an individual engineering discipline has met the minimum requirements of the profession. ABET covers the entire gamut of the spectrum of the profession: Engineering, Engineering Technology and related fields at the associate, baccalaureate, and advanced level (master's).

Through its society membership ABET sets the criteria or standards that are applied to the educational programs, taking into account all those items that are common to all engineers as well as those necessary for each individual discipline.

ABET is deeply involved in all aspects of education to insure that the accreditation criteria is adequate and corresponds to the "state of the art" of the profession. The responsibility for maintaining the strength of engineering education at a competitive level with the rest of the world as well as on the frontiers of new discoveries is part of the vision for all those in ABET. Most of the major studies in engineering education have either been initiated through ABET or have had significant ABET input.

Since its founding in 1932 ABET has collected the necessary data to carry out its accreditation function. This data is one of the means by which the compliance of the individual program is determined with regard to ABET criteria.

The ABET data is the only data that is verified by a team of professionals, as each accreditation action requires a campus and program visit where the facts as stated in the data are verified.

Unfortunately, ABET has not had the necessary outside support in order to publish or analyze in depth its data. This hearing is the first instance in which some of the ABET data is presented to the general public.

The data I am referring to covers the highlights of engineering programs only. Comparable data is available for engineering technology. The data is gathered from a total population of 259 institutions offering a total of 1321 specialized programs (1267 at the bachelors level and 54 at the master's level). From Chart B you will note that each year ABET averages visits to approximately 1/3 of all institutions and the same approximate ratio of programs. The yearly ABET data, though not representative of the same institution or program on a yearly basis, is representative of the total population and can safely be taken as representing what is occuring in the profession.

In connection with your area of interest our summary of accreditation actions in engineering is clearly shown in graphical form under Chart C. Note especially that there is a consistent number of programs that do not meet the accreditation criteria, (NA - not to accredit), as well as some previously accredited programs which are found to be so deficient that they will have their accreditation terminated within a three year period unless drastic changes are made to bring them into compliance, (SC - Show cause). These two categories together can be considered as failure rates and comprise from 11% to 16% of the total submitted for accreditation each year.

Programs which have minor violations of criteria are placed on report action (3R). This category can be considered to be one of the most favorable. Once the program deficiency is corrected a report on the correction, if accepted by ABET, is sufficient to extend the accreditation from 3 years to the maximum of 6 years. Note that 3R has changed from slightly less than 10% to a maximum of approximately 25% of total actions.

The most important curves in Chart C are those labelled 6V and 3V. 6V means the maximum term of accreditation - 6 years - and is given to those programs that meet the minimum ABET criteria. 3V is given to programs that have serious deficiencies whose correction can only be determined after an on site campus visit in 3 years.

You will note that in 1979-80 6V actions were at a 55% level. Coincident with the cry in the profession of "quality" deficiency, the 1981 accreditation actions of 6V confirmed the deficiency by reaching a low of approximately 38% which again, in 1983, dropped a few more percentage points to an all time low. The recovery has been slow in 1984 and '85, clearly showing how difficult it is for the institutions to institute corrective actions. Not because of lack of effort on their part to improve the quality of their offerings but simply, in my opinion, because many of the elements necessary for correction are not available in the market place - especially faculty. With the unprecedented growth of interest in engineering education - almost a threefold increase in undergraduate students in 10 years - a comparable increase in available graduate students has not materialized. Note that for the '85 year the 6V level is less than 2% higher than that in '84.

The 3V curve, in 1979 at a low of approximately 12%, has consistently increased as the problem with maintaining quality in engineering education exacerbates, thus now ('85) it is approximately at the same level as the 6V actions.

The above description should be sufficient to portray the reality of the serious deficiency in quality engineering education. When a large portion of the programs submitted for accreditation at a minimum level are unable to acquire the maximum term offered there is definitely a problem in the system.

Chart D is taken from the data of the Engineering Manpower Commission and points out quite vividly the large change in the population seeking an engineering education.

Chart E gives a summary of the criteria areas covered by ABET. Note that all issues that affect education are included in the criteria including the curricular subject matter required by engineering. The curricular content that is prescribed covers 3 years of a 4 year college baccalaureate program. Though the 4th year is not prescribed it is expected that it will be used to complete "...an integrated experience aimed at preparing the graduate to function as an engineer." We believe that the average engineering student accumulates a total of 136 semester credit hours by graduation starting with Calculus as the first course in the mathematics area. This compares to 120 semester credit hours required by a liberal arts and science baccalaureate with an entry point to mathematics of College Algebra, two or three courses below the engineering student.

Chart F provides you with a summary of the reasons cited by ABET for a specific program failing to obtain less than maximum term accreditation. Note that curriculum deficiencies are showing up as the most significant, followed by faculty - which undoubtedly relates to curriculum, - and by laboratories. Note that the laboratory issue has been addressed by the institutions and shows major improvement. This shows that corrective actions on equipment - inanimate objects - can be instituted by budgetary controls; however, intellectual property, namely faculty and curricula, can not be "purchased", must be developed and that takes time and people with the right motivation and ability as administrators, teachers, and students.

Chart G compares accreditation deficiencies as related to each term of accreditation for the 1985 academic year. As could be expected, the higher ratio of deficiencies per program corresponds to the most restrictive action.

To obtain data on individual items that affect the quality of programs ABET has prepared a compendium of data covering essential findings at each institution and comparing the summary for the 1982 to 1985 years. Chart H shows this data and gives ratios between the 1985/82 data. You will note that the institutions are trying to respond to pressures by mobilizing their resources in support of engineering. However, in spite of the effort made to date, some items such as the student faculty ratio have not improved over the past four years.

The salary data is presented in terms of a nine month academic year.

Charts I, J, and K show the same compilation of questions as shown on Chart H (the total of the engineering college) but broken down for some selected disciplines. In this case the data is presented for: Electrical Engineering, Mechanical Engineering and Civil Engineering. These disciplines were selected as being representative of a good cross section of the engineering population. Students show a marked interest - by the number of applicants - for Electrical Engineering. Mechanical Engineering at present, occupies the median level of interest among students with Civil Engineering being among the disciplines which draw less interest from students. This data is presented without comment or analysis.

Chart L is an attempt to provide you with a comparison obtained from a representative sampling of the quality of entering students as determined through the standard college admission tests - the Scholastic Aptitude Test and the American Collegiate Test. You will note that the ratio of students applying for admission and the number admitted has not changed markedly between 1970 and 1985, however the absolute numbers have increased significantly. Contrary to expectations the average composite scores of the college tests has not changed appreciably between 1970 and 1985. Of special interest is to note that the average admissions scores hit an all time low in 1975. Thus by comparing to the immediate past, especially 1975, it can be said that the quality of the entering students has increased significantly.

The above material is one way in which ABET wants to contribute to your deliberations. The data speaks for itself. Any analysis will confirm that there is a problem with maintaining quality in engineering education and will support some of the remedial measures suggested at these hearings by representatives from the engineering profession.

A very important issue which is obvious at this time is the need to separate science data from that of engineering. Both groups are different and should not be mixed. When the data is presented in a joint form, the perspective of what each group requires is completely clouded.

ABET is ready to assist in any way it can to help alleviate the problem areas in engineering education. One way we can be effective is by providing you with this data. Thank you for the opportunity to bring it to your attention.

AVAILABL

CHART A

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY

PARTICIPATING BODIES

American Academy of Environmental Engineers (AAEE)

American Congress on Surveying and Mapping (ACSM)

American Institute of Aeronautics and Astronautics, Inc. (AIAA)

American Institute of Chemical Engineers (AIChE)

American Institute of Mining, Metallurgical and Petroleum Engineers (AIME)

American Nuclear Society (ANS)

American Society of Agricultural Engineers (ASAE)

American Society of Civil Engineers (ASCE)

American Society for Engineering Education (ASEE)

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)

The American Society of Mechanical Engineers (ASME)

Institute of Industrial Engineers, Inc. (IIE)

The Institute of Electrical and Electronics Engineers, Inc. (IEEE)

National Council of Engineering Examiners (NCEE)

National Institute of Ceramic Engineers (NICE)

National Society of Professional Engineers (NSPE)

Society of Automotive Engineers (SAE)

Society of Manufacturing Engineers (SME)

Society of Naval Architects and Marine Engineers (SNAME)

MEMBER BODIES

American Society for Nondestructive Testing, Inc. (ASNT)

Society of Engineering Science, Inc. (SES)

CHART B

ENGINEERING ACCREDITATION ACTIONS

1978 - 1985

YEAR	ACTIONS	UNIVERSITIES
1978	280	62
1979	283	73
1980	151	43
1981	241	57
1982	308	67
1983	353	88
1984	327	77
1985	327	90

Each action represents one program which was submitted for accreditation or reaccreditation at a college or university, e.g. Mechanical Engineering, Computer Engineering, etc.

TERMS OF ACCREDITATION

6V =6 years

3R =3 years, with a report due before then. Acceptance of the report by ABET extends the term by another 3 years.

3V =3 Years

SC =Show cause why accreditation should not be terminated.

NA =Not accredited.

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ENGINEERING ACCREDITATION ACTIONS

1979 THRU 1985

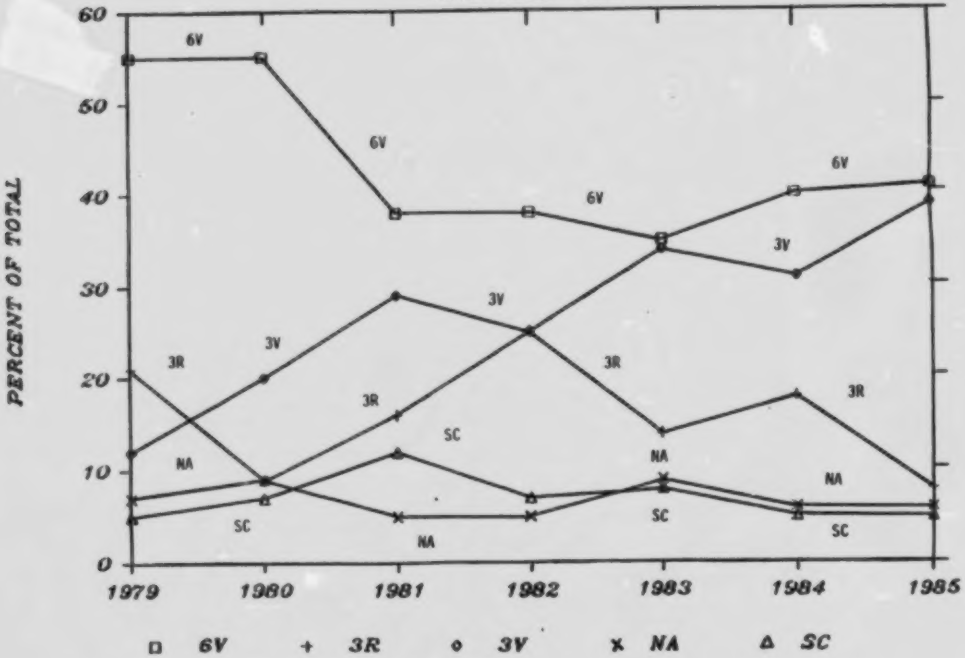

CHART C

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HISTORICAL SUMMARY
ENGINEERING ENROLLMENTS IN FALL, 1984
As Compared With Earlier Years

CHART D

	Fall 1973	Fall 1974	Fall 1975	Fall 1976	Fall 1977	Fall 1978	Fall 1979	Fall 1980	Fall 1981	Fall 1982	Fall 1983	Fall 1984
Engineering Students												
Freshman Year, Full-Time	51,925	63,444	75,343	82,250	88,780	95,805	103,724	110,149	115,280	115,303	109,638	104,629
Sophomore Year, Full-Time	40,519	45,935	55,891	63,003	70,326	72,150	78,594	84,962	87,519	89,785	89,515	83,326
Junior Year, Full-Time	41,673	43,007	94,338	56,835	64,721	69,816	74,928	80,024	86,633	90,541	91,233	89,099
Senior Year, Full-Time	48,366	44,538	47,070	51,692	60,109	68,260	77,823	84,442	92,414	102,055	109,036	109,285
Fifth Year, Full-Time	4,222	4,175	3,737	4,055	5,312	5,206	5,419	5,520	5,731	5,706	6,722	6,236
TOTAL FULL-TIME UNDERGRAD	186,705	201,099	231,379	257,835	289,248	311,237	340,488	365,117	387,577	403,390	406,144	392,575
Part-Time Undergraduates	15,692	16,689	17,041	19,844	20,634	22,843	25,811	32,227	32,825	31,940	35,061	34,504
Master's Degree, Full-Time*	22,588	21,999	26,004	25,316	26,876	26,060	27,923	29,870	32,310	33,968	38,826	37,538
Doctorate, Full-Time	11,904	10,628	11,281	10,963	12,359	12,321	13,461	14,465	15,472	16,442	18,540	19,459
TOTAL FULL-TIME GRADUATE STUDENTS	34,492	32,627	37,285	36,379	39,235	38,381	41,384	44,335	47,772	50,410	57,366	56,997
Part-Time Grad. Students	26,114	27,572	27,173	26,842	25,065	24,133	25,768	28,250	29,818	31,589	33,674	35,058
Number of Schools	285	282	291	289	289	276	286	287	286	286	292	----
Number of schools with at least one curriculum accredited by ABET	**	**	**	**	**	**	239	246	250	249	258	----

* Includes Engineer Professional Degrees

** Not available prior to 1979

E.M.C. Data July 1985

CHART E

ENGINEERING ACCREDITATION

CRITERIA AREAS

GENERAL/PROGRAM

1. Faculty
2. Curricular Objective and Content
    - A. One Year of an Appropriate Combination of Mathematics and Basic Sciences
    - B. One Year of Engineering Sciences
    - C. One Half-Year of Engineering Design
    - D. One Half-Year of Humanities and Social Sciences
3. Student Body
4. Administration
5. Institutional Facilities
6. Institutional Commitment

Additional/Different Criteria Exist for:

1. Non-Traditional Programs
2. Innovative and Experimental Programs
3. Cooperative Education

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REASONS FOR LESS-THAN-MAXIMUM ENGINEERING ACCREDITATION ACTIONS

AREA OF CONCERN	1982-83		1983-84		1984-85	
	No.	%	No.	%	No.	%
Faculty	94	19%	104	24%	63	15%
Curriculum	147	30%	130	30%	169	40%
Advising	32	7%	33	8%	42	10%
Laboratories/Equipment	127	26%	108	25%	71	17%
Administration	37	8%	42	10%	34	8%
Low Enrollment	6	1%	2	-	14	3%
Resources Allocation	41	8%	15	3%	34	8%
Deficiencies Cited	484		434		427	
Programs Reviewed	230		186		183	

CHART F

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CHART G

BREAKDOWN OF REASONS FOR LESS-THAN-MAXIMUM
ENGINEERING ACCREDITATION ACTIONS
1984-85

AREA OF CONCERN	3R	3V	SC	NA	TOTAL
Faculty	6	42	9	6	63
Curriculum	14	104	32	19	169
Basic Science/Math	(0)	(9)	(5)	(2)	(16)
Engineering Science	(0)	(5)	(3)	(2)	(10)
Design	(4)	(44)	(16)	(7)	(71)
Humanities	(3)	(7)	(3)	(3)	(16)
Other	(7)	(39)	(5)	(5)	(56)
Advising	11	26	2	3	42
Laboratories/Equipment	9	54	7	1	71
Administration	4	24	3	3	34
Low Enrollment	1	10	1	2	14
Resources Allocation	1	31	2	0	34
Total Deficiencies Cited	46	291	56	34	427
Programs Reviewed	26	124	20	13	183
Deficiencies per Program	1.77	2.35	2.80	2.62	2.33

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

ENGINEERING COLLEGE AS A WHOLE ALL INSTITUTIONS

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENTIRE INSTITUTION					
Student/Faculty	15.64	16.65	15.44	15.17	.97
Tot. Educ. Exp./Faculty	$115,698	$118,661	$148,348	$144,940	1.25
Tot. Educ. Exp./Student	$ 8,046	$ 7,768	$ 12,398	$ 9,554	1.19
ENGINEERING COLLEGE					
U.G. Student/Faculty	24.58	22.29	18.79	20.33	.83
Support Pers./Faculty	.43	.4	.41	.47	1.09
Oper. Exp./Faculty	$ 7,663	$ 5,833	$ 11,059	$ 8,028	1.05
Oper. Exp./U.G. Student	$ 567	$ 487	$ 1,708	$ 395	.70
Capital Exp./Faculty	$ 4,825	$ 8,151	$ 9,210	$ 11,120	2.30
Travel Exp./F/T Faculty	$ 608	$ 1,075	$ 777	$ 891	1.47
Computer Exp./U.G. Student	$ 171	$ 417	$ 1,145	$ 286	1.67
B.S. Degrees/Faculty	3.9	4.01	5.54	3.79	.97
Degree Productivity Index**	5.35	5.42	7.66	5.95	1.11
High Salary-Professor	$ 43,616	$ 55,422	$ 52,927	$ 54,204	1.24
Mean Salary-Professor	$ 34,862	$ 38,077	$ 41,522	$ 43,069	1.24
Low Salary-Professor	$ 28,336	$ 29,891	$ 33,021	$ 34,760	1.23
High Salary-Assoc. Prof.	$ 31,665	$ 35,259	$ 37,915	$ 38,601	1.22
Mean Salary-Assoc. Prof.	$ 27,369	$ 30,407	$ 32,613	$ 33,928	1.24
Low Salary-Assoc. Prof.	$ 23,591	$ 25,319	$ 27,823	$ 29,118	1.23
High Salary-Asst. Prof.	$ 26,613	$ 29,187	$ 31,356	$ 33,075	1.24
Mean Salary-Asst. Prof.	$ 23,688	$ 26,204	$ 28,227	$ 29,369	1.24
Low Salary-Asst. Prof.	$ 21,007	$ 23,093	$ 23,885	& 25,597	1.21
TOTAL NUMBER OF INSTITUTIONS	83	65	86	77	

* Students (undergraduates) and Faculty are FTE except where noted.
** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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CHART H

ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

ELECTRICAL ENGINEERING PROGRAMS

CHART I

	ACADEMIC YEARS				
ITEM*	1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	27.8	26.13	20.07	21.95	.78
Support Pers./Faculty	.31	.27	.29	.29	.93
Grad. Assts./Faculty	.61	.76	.49	.54	.88
Oper. Exp./Faculty	$ 3,073	$ 2,611	$ 3,843	$ 5,275	1.71
Capital Exp./Faculty	$ 4,035	$ 8,896	$ 14,331	$ 13,992	3.46
Capital Exp./U.G. Student	$ 166	$ 475	$ 1,395	$ 638	3.84
Travel Exp./F/T Faculty	$ 654	$ 943	$ 1,122	$ 813	1.24
Computer Exp./U.G. Student	$ 119	$ 132	$ 965	$ 248	2.00
B.S. Degrees/Faculty	3.72	4.36	3.66	4.10	1.10
Degree Productivity Index	5.06	6.07	5.85	6.18	1.22
Required Sem. Hrs. for Degree	132.56	132.46	142.61	145.67	1.09
Lab Area/Faculty (Sq. Ft.)	697	690	619	624	.89
Lab Area/U.G. Student(Sq. Ft.)	27	31	215	28	1.03
High Salary-Professor	$ 41,567	$ 46,604	$ 47,291	$ 48,480	1.16
Mean Salary-Professor	$ 35,086	$ 39,348	$ 40,800	$ 42,154	1.20
Low Salary-Professor	$ 30,302	$ 34,025	$ 35,283	$ 37,157	1.22
High Salary-Associate Prof.	$ 30,234	$ 33,683	$ 34,888	$ 36,433	1.20
Mean Salary-Associate Prof.	$ 28,136	$ 30,888	$ 32,568	$ 33,738	1.19
Low Salary-Associate Prof.	$ 26,404	$ 27,846	$ 30,241	$ 31,633	1.19
High Salary-Assistant Prof.	$ 26,472	$ 28,291	$ 29,684	$ 31,454	1.18
Mean Salary-Assistant Frof.	$ 24,954	$ 27,220	$ 28,126	$ 29,877	1.19
Low Salary-Assistant Prof.	$ 23,787	$ 26,032	$ 26,533	$ 27,811	1.16
TOTAL NUMBER OF INSTITUTIONS	52	36	51	49	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{1\ \text{B.S.} + 1.5\ \text{M.S.} + 3.0\ \text{PhD}}{\text{FTE}}$

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

MECHANICAL ENGINEERING PROGRAMS

CHART J

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	23.63	23.48	18.17	17.89	.75
Support Pers./Faculty	.26	.31	.64	.26	1.00
Grad. Assts./Faculty	.38	.58	.51	.54	1.42
Oper. Exp./Faculty	$ 3,217	$ 3,038	$ 3,334	$ 4,140	1.28
Capital Exp./Faculty	$ 2,188	$ 4,950	$ 11,135	$ 8,042	3.67
Capital Exp./U.G. Student	$ 117	$ 297	$ 3,088	$ 449	3.83
Travel Exp./F/T Faculty	$ 644	$ 1,214	$ 1,181	$ 1,917	2.97
Computer Exp./U.G. Student	$ 86	$ 117	$ 1,245	$ 300	3.48
B.S. Degrees/Faculty	3.64	4.47	4.80	3.50	.96
Degree Productivity Index	4.57	5.75	6.49	4.48	.98
Required Sem. Hrs. for Degree	133.13	131.30	140.96	145.30	1.09
Lab Area/Faculty (Sq. Ft.)	982	998	960	983	1.00
Lab Area/U.G. Student(Sq. Ft.)	47	49	451	55	1.17
High Salary-Professor	$ 39,539	$ 46,903	$ 48,741	$ 48,189	1.21
Mean Salary-Professor	$ 34,646	$ 38,849	$ 41,612	$ 41,904	1.20
Low Salary-Professor	$ 30,358	$ 32,738	$ 35,541	$ 37,235	1.22
High Salary-Associate Prof.	$ 29,068	$ 33,616	$ 34,948	$ 36,324	1.24
Mean Salary-Associate Prof.	$ 27,487	$ 31,213	$ 32,533	$ 34,194	1.24
Low Salary-Associate Prof.	$ 25,706	$ 28,848	$ 29,918	$ 31,942	1.24
High Salary-Assistant Prof.	$ 25,282	$ 28,023	$ 30,567	$ 31,354	1.24
Mean Salary-Assistant Prof.	$ 23,879	$ 27,262	$ 28,954	$ 29,519	1.23
Low Salary-Assistant Prof.	$ 22,242	$ 26,526	$ 27,498	$ 28,004	1.25
TOTAL NUMBER OF INSTITUTIONS	45	36	57	50	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY
ACCREDITATION QUESTIONNAIRE DATA

CIVIL ENGINEERING PROGRAMS

CHART K

ITEM*	ACADEMIC YEARS 1982	1983	1984	1985	1985/1982 RATIOS
ENGINEERING COLLEGE					
U.G. Student/Faculty	19.26	15.27	13.1	13.3	.69
Support Pers./Faculty	.28	.29	.3	.29	1.03
Grad. Assts./Faculty	.47	.66	.56	.42	.89
Oper. Exp./Faculty	$ 2,444	$ 2,783	$ 3,450	$ 3,227	1.32
Capital Exp./Faculty	$ 2,984	$ 5,734	$ 10,089	$ 6,622	2.21
Capital Exp./U.G. Student	$ 180	$ 409	$ 1,544	$ 498	2.76
Travel Exp./F/T Faculty	$ 734	$ 1,194	$ 10,297	$ 829	1.12
Computer Exp./U.G. Student	$ 101	$ 228	$ 475	$ 261	2.58
B.S. Degrees/Faculty	3.88	3.44	3.65	3.18	.81
Degree Productivity Index	5.38	5.04	5.01	4.62	.85
Required Sem. Hrs. for Degree	133.45	132.32	142.51	144.95	1.08
Lab Area/Faculty (Sq. Ft.)	955	1,113	881	848	.88
Lab Area/U.G. Student(Sq. Ft.)	76	86	116	64	.84
High Salary-Professor	$ 39,520	$ 46,908	$ 47,536	$ 45,960	1.16
Mean Salary-Professor	$ 34,436	$ 39,407	$ 41,213	$ 41,481	1.20
Low Salary-Professor	$ 30,246	$ 33,608	$ 36,769	$ 37,079	1.22
High Salary-Associate Prof.	$ 29,034	$ 33,556	$ 35,188	$ 34,437	1.18
Mean Salary-Associate Prof.	$ 27,112	$ 30,788	$ 32,550	$ 32,465	1.19
Low Salary-Associate Prof.	$ 25,581	$ 28,026	$ 29,736	$ 30,782	1.20
High Salary-Assistant Prof.	$ 25,644	$ 28,522	$ 29,650	$ 29,621	1.15
Mean Salary-Assistant Prof.	$ 23,776	$ 27,243	$ 28,297	$ 28,933	1.21
Low Salary-Assistant Prof.	$ 22,706	$ 26,138	$ 26,764	$ 27,955	1.23
TOTAL NUMBER OF INSTITUTIONS	41	40	46	42	

* Students (undergraduates), Assistants, and Faculty are FTE except where noted.

** Degree Productivity Index = $\frac{\text{1 B.S. + 1.5 M.S. + 3.0 PhD}}{\text{FTE}}$

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CHART 1

SURVEY ON QUALITY OF ENTERING ENGINEERING STUDENTS

1	2	3	4	5	6	7	8	9	10
	UNDERGRADUATE DATA								GRADUATE DATA
Year	Approx. # of Students Applying for Admission to Engineering	Approx. # Admitted	Avg. SAT Composite Score	Avg. SAT Math	Avg. SAT Verb.	Avg. ACT Composite Score	Avg. ACT Math	Avg. ACT Verb.	Average GRE Composite Score
1970	1741.5	800.9	1181.8	614.4	541.6	24.26	27.0	20.78	1193
1975	1562.3	955.0	1129.2	601.0	527.6	23.32	25.86	19.86	1191.3
1980	2519.4	1206.0	1168.6	617.2	536.0	23.54	25.45	20.43	1176.3
1985	2576.9	1172.1	1184.6	632.0	545.2	25.10	27.13	21.89	1162

1970 sample represented 19.0% of engineering freshman population
1975 sample represented 27.9% of engineering freshman population
1980 sample represented 26.3% of engineering freshman population
1985 sample represented 27.1% of engineering freshman population

Survey questionnaire sent to 30 engineering schools out of 258 with ABET-accredited programs. Response was obtained from 24 schools.

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Mr. **Fuqua**. Thank you.

Dr. Nordby.

Dr. **Nordby**. Thank you.

I would like to comment about some of the deficiencies in the accreditation examination of institutions.

The main three deficiencies, as you will see in your charts, are faculty deficiencies and laboratory equipment and design in the curriculum.

We don't have a good handle on this, as Ms. Vetter pointed out, as to the number of students, and especially foreign national faculty or foreign national graduate assistants and graduate students, so we can only measure it qualitatively and not quantitatively as well as we would like.

One of our—and I would say the dominant deficiency we find is shortage of faculty. We are not producing the number of Ph.D.'s we once did. Those figures a decade ago were about 5,500 per year. It has dropped as low as 3,500 per year, and I think now it is coming up a little bit and, hopefully, is at the rate of about 4,000 per year. But 40 percent of those are foreign nationals, which is about the only supply we can have in the institutions. We get strong competition from industry for the Ph.D.'s, who cannot often hire the foreign nationals for other reasons, so that has brought a near dominance in hiring for faculties to foreign nationals.

We sometimes quote that we have vacancy rates of 8 percent in our positions in institutions, in the engineering faculties, but that is somewhat misleading because universities like mine do not budget vacant positions. If we cannot fill them, we do not budget them, so they are budgeted elsewhere, so there is a bigger shortage than those figures indicate.

Actually, we have increased our enrollments about 70 percent over the last 5 or 6 years relating to Dr. Reyes-Guerra's accreditation chart, but we have only increased our faculty during that period of about 10 percent. One thing we cannot be accused of is not increasing our productivity. We are one industry that has increased our productivity in terms of degrees tremendously.

Related to the faculty shortage is the design element of the curriculum. The end point of engineering education is to be able to design for the marketplace a product, a system, a building, or whatever. Because of faculty shortages, I believe we have not been able to teach that kind of process as well as we should. By design, that means establishing objectives, criteria, synthesis, analysis, construction, testing and evaluation, open-ended problems, development and use of design methodology, formulation of design problem statements and specifications and consideration of alternative solutions.

It should also include a variety of realistic constraints such as economic factors, safety, reliability, aesthetics, ethics, and social impact. Those are difficult things to teach without low student-faculty ratios or very individual contact, which faculty shortages do not permit.

The other serious deficiency is laboratory equipment, particularly in the computer line. This is being partially corrected, as Dr. Reyes-Guerra commented, and industry has been very helpful in helping us satisfy this need. But we still have serious shortages, especially at the research level, having the necessary sophisticated equipment to do that job.

I would like to additionally comment on what industry is telling us, and I read the news reports of this committee and the confusion you may be in by hearing comments like I will make now. Industry, of course, is telling us that the technical ability of our graduates is adequate; some say it is excellent and the best they have ever had. On the other hand, there are serious deficiencies which they also tell us about, and I suppose there is a "good news" and "bad news" story to this. The good news is that engineering education is doing as well as it can. The bad news is also that it is doing as well as it can. In this unprecedented global competition we are in, the engineering support the Nation needs must be much stronger than it has been in the past.

Industry then tells us that our computer knowledge, the training in computers, is marginally adequate, that engineers do not cross over between technical disciplines very well, that they become too narrow in their technical disciplines. But many of the things that they comment about are nonengineering. They do not understand the business and management environment. They are not attuned to the global economics that we are now in and the productivity of the Nation and productivity and profit motivations of the companies they work for. They are not as good team workers as they should be. This is a strong comment over the years, not only for the past few years, but they need to improve in written and oral communication. They must convince clients, sell their product, and communicate to the general public what they are doing in this day and age, and they are not as good at that as they should be. They are not prepared for the legal, ethical, and social problems that they face in industry and are poorly prepared in that respect. All of them say, of course, that it would take more than 4 years to educate such a person, and it also presumes that somehow in college we can inoculate them with all that information for life, which I don't think we can.

It reminds me of the study that was made some years ago by Purdue University, by a survey of about 6,000 of their graduates, and as the graduates proceeded through life, they had different needs. When they were out up to 5 years, the graduates said they needed more design capability; from 5 to 10 years, they said they needed more engineering science; from 10 to 15 years, they said they needed more management and business training; and 20 to 25 years, they needed more humanities, social science, and more general education. I guess that just tracks the need for changing talents as we proceed up the management chain.

Part of our problem, then, is that engineers now take 4.5 to 4.7 years to get through school. We have a 4-year curriculum on paper, but very few can complete it in that time. So if we were to extend the time in school and, say, have a 5-year curriculum to add many of the requirements I have spoken about or that industry would like us to have, it, in effect, is increasing our curriculum to maybe 5.7 or nearly 6 years of training.

Thank you.

PANEL 2 DISCUSSION

Mr. **Fuqua**. Thank you very much.

Ms. Vetter, it appears that your staff produces a large number of reports and data summaries and overviews on scientific manpower. Who is your primary user of that?

Ms. **Vetter**. I don't think there is a primary user. It is used by many of the Government agencies, by industry, by academic people. I think our distribution lists are roughly a thirdish from those three sectors.

Mr. **Fuqua**. Where does your primary funding come from to provide this information?

Ms. **Vetter**. I guess the primary funding comes from sale of publications. In addition, there is some funding from the scientific societies that make up the commission, that are its constituent members.

Mr. **Fuqua**. But they don't fund all of it?

Ms. **Vetter**. Oh, no, no, about 10 percent, and about 10 percent comes from contributions from industry. We usually have about one grant at a time that we are working on, usually from NSF, and all the rest of it is from sale of publications that we write and produce.

Mr. **Fuqua**. Is the support adequate for the needs?

Ms. **Vetter**. No, sir. We are in very serious trouble at the moment.

Mr. **Fuqua**. Without the type work that your organization does, is there any other group that might be expected to carry on this type of work?

Ms. **Vetter**. Not that I know of. Nobody else does it now.

Mr. **Fuqua**. Let me ask—and all of you may wish to comment—how reliable are the projections for supply and demand, and who makes the predictions now?

Ms. **Vetter**. Well, a lot of people make them. The ones most widely used are those made by the Bureau of Labor Statistics, occasionally by NSF, which has at various times done more projecting that it has at others; sometimes through grantees from NSF. Projections are made by people working on a grant from NSF. Even people like me occasionally try on the basis that we think we can do a better job than somebody else has done.

None of them, if you go back and look over time, none of them ever turn out to be very right. The first ones I ever tried were about 10 years ago, and the one place where I turned out to be absolutely right was in the number of women who would get degrees in engineering up through 1984. I was projecting a 10-year base, and I was off by seven degrees on last year's degrees, of which I was very proud.

The NCES data for the same year were off by 42 percent. But that is only because I understood that women were not a "sometime" thing in engineering, and they did not.

Other projections are made by—oh, some of the individual groups out in society make them. The American Electronics Association, for example, makes some projections. None of them turn out very well. But that is the major source.

Mr. **Lujan**. Why do we do them?

Ms. **Vetter**. Oh, because even though we know they won't necessarily turn out right, we have to do a pretty good job of looking ahead. We do it all the times in every aspect of our lives. You people do it here in Congress all the time. You have to look ahead.

Mr. **Fuqua**. We are not very right, either, many times. [Laughter.]

Ms. **Vetter**. Nobody is ever very right. Any of us who had the perfect crystal ball would do far better, but we still have to plan ahead, even though we recognize that things change the plans, and we adapt as we go along, but we still have to continue to plan ahead.

Dr. **Reyes-Guerra**. I would like to address the question you made from the point of view of engineering. I am also a member of the Engineering Manpower Commission. Ten years ago, I headed a committee that looked into supply and demand in engineering.

We concluded that we could only give a projection of demand with a fair amount of accuracy for the next 9 months, and that was within an 85-percent degree of accuracy. Anything past 9 months to 1 year, it started deteriorating so fast that it just didn't have any meaning whatsoever. We could be, in 2 years, less than 30 percent accurate.

We concluded that the engineering profession is such that it is very difficult to do, especially since the engineering profession depends so much on contract work being done by major industries.

The problem with the supply and demand formula that we were looking at, and we have kept on looking at for the number of years, is that when you have competitive bidding for major projects, each bidder has to present a picture of what their needs would be in case they won that particular bidding, and therefore you have five or six companies presenting a picture in one particular discipline of engineering of, let's say, 50,000 engineers, when there are only 5,000 needed for the project. But each one feels they might get that project and it might be a 10-year project.

I would say that in engineering, you can just dispense with any of that statistic because it just does not prove right. Last year, the Engineering Manpower Commission again attempted to find out how to do it. We studied the formula of a very well-known engineer, who started his formula at the Polytechnic Institute of New York in the 1940's. Well, the formula is now a compendium, because each year he corrects it, and it has not been able to predict anything with success. I think, in engineering, it is a lost cause.

Mr. **Fuqua**. What about the other disciplines like chemistry or physics or mathematics?

Dr. **Reyes-Guerra**. I could not speak to those, sir, because I am just really very much familiar with engineering. But the scientific area, I believe they probably have the same problem as we do.

Ms. **Vetter**. I think the major difference, the reason we cannot do a good job, is because we have to recognize the difference between demand and need, and that difference is money.

You can anticipate the need for whatever—the scientists, the engineers, the anything—if you are going to clean up the environment or try to cure cancer or clean up the Nation's infrastructure, and those will have quite different technological requirements, for example, those three things, or do the President's "Star Wars" initiative or other kinds of defense initiatives. You can project need for any of those activities or any combination of them. What you cannot project is what a changing Congress and a changing administration will bring about in the way of Federal budgets in those areas that are technologically dependent and have high-manpower components, and it changes both the internal demand—that is, whether you need more physicists or more chemists or more biologists or whether you need more engineers—depending on which of these activities you do. It changes the kind of engineers you need, if it is engineers you want, and it also changes the numbers.

So none of us have ever been able to figure out well enough in advance the combination of the actual cost and the appropriations for those things which are so technologically dependent. Right now the engineers are doing fine because we are in a strong defense effort.

If the next administration should change that, engineers would be in a bad slump again. Aeronautical engineers would be in terrible trouble, and yet we are now predicting, or NSF is predicting, projecting, shortages of aeronautical engineers. But that would change very fast if the defense budgets changed.

Dr. **Reyes-Guerra**. May I just give you another comment on this? As long as, in our educational system, those pursuing liberal arts and sciences and the humanities are not becoming technologically aware and technologically literate, engineering will always be a high-demand profession, simply because we train the technologically literate person. Even though we lack sometimes a degree of specialization in some of the engineering graduates, this is why there are so many at the baccalaureate level not continuing their education and going into industry. Industry is taking them because of their technological literacy, not necessarily because they are engineers, but they are the only product of our colleges that brings that technological literacy.

I think the entire picture would change if, in higher education, the other fields, the social sciences and the humanities, would start to insert technological literacy into their curricula, because then these people could fit into the world we live in, which is a technological world. So engineers will always do well as long as this continues to be the pattern of higher education.

Mr. **Fuqua**. In other words, the unknown factors of the future then limit the ability to use trends and patterns that were developed in the past?

Ms. **Vetter**. You can always use those trends and patterns, and, of course, they do provide a very useful model. But one of the things we are really trying to project is balances and imbalances between supply and demand—that is what we really want to know—and so we make projections and we say, as an example, NSF has now said we probably will not have enough aeronautical engineers.

The student, now a senior in high school, who has always been interested in airplanes and thinks, "Hey, that is a wonderful thing to do," and if enough people read that projection, believe it, go into aeronautical engineering, graduate in 4½ years, and meantime, we have changed administrations, and suppose we have stopped the concentration on defense that we now have, where are we? We are suddenly terribly overloaded with aeronautical engineers, and the projection is exactly backward.

But one of the reasons the projection is backward is because, if it was a good one in the first place, it will always turn out wrong, because people will react to it in a way that would be natural, given what the projection was. So sometimes it is nice to be able to say your projections turned out wrong.

If you try to project degree data, I think that is a little easier. Supply data is hard. Degree data, which is one part of supply data, is not that hard, until you start getting down into tight subfields.

Right now, most of the kids who want to go into engineering, a very large number, want to go into electrical engineering, because that is where the bucks are, that is where the demand is. Suppose, instead, Congress decided that it was going to fix all the highways and all the bridges and all the falling-down buildings and that sort of thing, do the infrastructure.

The civil engineers, which have been at the very bottom now for the last several years, because they were the last hired, suddenly the demand for civil engineers would be tremendous, and that is not what we would have. We would have electronic engineers, because they believe what is happening now will be what is happening in the future, and the only thing we are sure of is that something unexpected will happen, and the future will change, but we don't know which way.

Mr. **Fuqua**. Mr. Lujan.

Mr. **Lujan**. Something you said, Dr. Reyes-Guerra, is kind of swimming around in my mind, and I don't know how to correlate the two things.

You talked about how the basic education that an engineer would get allows him to adapt. Now, supposing we, all of a sudden, have a surplus of electrical engineers, and we start, as Ms. Vetter says, to do the civil work. Are you saying that, with a good foundation, an electrical engineer could move into civil engineering?

Dr. **Reyes-Guerra**. Well, the conversion is a little complicated. However, the technological basic knowledge—they all have the same math, they all have basically the same physics and the same chemistry. The problem is the motivation.

If you became an electric engineer, you want to practice electrical engineering. That is what you went into it for. So you try to stay with it, and even though the employment market might be soft, you try to continue and you struggle because you want to be an electrical engineer.

However, you can. It has been done. The Air Force has been doing it at the Air Force Institute of Technology, transforming civil engineers into electrical engineers in an 18-month intensive course. It has been done at several universities throughout the country. So it can be done. The transformation can be done. The individual's motivation for transformation from one field to another is the difficult thing.

But, yes, in some of the simple functions—simple in terms of engineering know-how—but for which it is necessary to be an engineer, the lower scale of activity, yes, with very little transition, an electrical engineer could handle that.

As a matter of fact, I am glad you mentioned electrical engineering, because the father of transportation in this country, who just won the Distinguished Service Award from the National Society of Professional Engineers, is an electrical engineer who is the world's expert in transportation engineering, and he transformed very readily.

Mr. **Lujan**. I was looking at your charts, trying to make as much sense from them as I could, and they do make a lot of sense. On your chart F, I assume that the percentages that you show are the failure rate, if you want to use that terminology.

Dr. **Reyes-Guerra**. Yes.

Mr. **Lujan**. So our faculty is better; our laboratory equipment is better; but the curriculum seems to be what is really off kilter. It really doesn't make a lot of sense why that should be. If our faculty is better and our equipment is better, why shouldn't our curriculum be better? Would it necessarily follow?

Dr. **Reyes-Guerra**. Well, it is better in terms that there has been a reduction in the deficiencies noted by the faculty over those years. But the problem with the curriculum is the problem that Dr. Nordby alluded to, that we are now teaching too many courses with too few faculty. So even if the quality of the person is good, the amount of contact with students that that faculty member has is very limited, and it hampers the ability of the institution to offer as many of the courses as they should for a given discipline in the depth they should, because they just don't have that many faculty, and the increase in students is tremendous.

Mr. **Lujan**. So that the 15 percent that you referred to as far as faculty is concerned in 1984 and 1985 refers to quality rather than numbers?

Dr. **Reyes-Guerra**. Yes, sir.

Mr. **Lujan**. Your last chart, chart L, the GRE composite scores for graduate students keeps decreasing. Are we giving a "less better" education—not wanting to say "worse"—but not quite as good?

Dr. **Reyes-Guerra**. This was a finding that I did not expect to get but I did get. The admissions at the universities vary. It just so happens that for graduate school in the college of engineering, the GRE is not that widely used. I thought it was. The university as such uses it, but the engineering component of the university does not rely for graduate education as much on the GRE as we thought they did.

When I looked at the number of schools that were reporting out the usage of the GRE, it was less than half of the sampling I took, and these are the numbers that they came up with. So they use, more than anything else, references from faculty from the colleges in which the student got his undergraduate education. That is the core that is used by the college of engineering in admitting students to the graduate school. The GRE is very insignificant.

Mr. **Lujan**. That is very surprising to me, because I was under the impression that your test scores, whether they are the SAT or ACT or your GRE, that those really played a very important part in whether you get admitted or not.

Dr. **Reyes-Guerra**. Not in engineering.

Dr. Nordby, would you like to comment?

Dr. **Nordby**. I think, from our point of view, the most reliable admission standard is their grade point average in high school. We do place some emphasis on these scores, but we use a combination of the score and the admission exam, either the SAT or the ACT. We rely on performance at the graduate level quite a bit, and recommendations of the professor that he worked with more than the GRE.

Mr. **Lujan**. Well, but they haven't been in graduate school, so you don't have performance. Do you mean performance in undergraduate work?

Dr. **Nordby**. Well, they have the recommendations of their undergraduate instructors and their performance in their undergraduate engineering curriculum.

Dr. **Reyes-Guerra**. I will give you another indicator of this GRE and how difficult it is to use it in engineering. You have probably heard in prior testimony that a large number of the entering graduate students are foreign born and foreign students. They score very low on the GRE. Though their theoretical and other knowledge is very high, the cultural problem makes them score very low on the GRE, which is not geared to differentiate between foreign and nonforeign. So this is another reason why the schools of engineering have sort of decreased the usage of the GRE, because they have been taking as graduate students a large proportion of foreign students. You have probably heard that some institutions go as far as 55 and 60 percent graduate students.

Mr. **Lujan**. Well, that is really very surprising to me. Just on a personal note, I have got a daughter that is wanting to get into medical school, and she has applied, and they say, well, you know, if your Med SAT's are very good, or MEDCAT or whatever—anyway, your medical SAT's or whatever——

Dr. **Reyes-Guerra**. We just don't have those.

Mr. **Lujan** [continuing]. Then you get early admission. It seemed to me that the universities did, graduate schools did place a lot of emphasis on them. I had better not be guided by that, because she had better get good ratings on them, anyway.

Thank you.

Dr. **Reyes-Guerra**. Medical schools are a little different than engineering schools.

Mr. **Lujan**. Thank you.

Mr. **Fuqua**. Mr. Slaughter.

Mr. **Slaughter**. In looking at chart L, in 1975, the SAT scores were down for students entering engineering, as I read it. Do you think that was a significant reduction, and do you have any idea why was that reduction?

Dr. **Nordby**. In this whole record, I don't think there is a lot of deviation. They are all, in the math, over the 600 mark, and I think going from 601 to 632 in that element is not a great variation. It is some variation, and I think we can tell the difference between 1975 and 1985, but I cannot say that it is—it is not a trend at all.

I think what I would say is that we are getting about the same quality student that we have always had. It goes up and down a little, but it is about the same, although it appears that maybe in 1985—and those are students we have just admitted and have not assessed through any program yet—there may be an upswing. Especially, the verbal is coming up quite a bit since 1975.

Engineering is sort of a self-selecting field. Just about always, I think, 85 percent of the students come from the upper 25 percent of the high school class, and that is just about automatic. They just don't attempt it. They sort of self-assess themselves and enter on their own estimate of whether they have the ability.

Mr. SLAUGHTER. Another question, Mr. Chairman.

On the question of Ph.D.'s, which I understand that you all regard as the basic problem of maintaining and raising standards in engineering education, do you think it is the cost of obtaining a Ph.D. education or the lack of attractive opportunities or economic reward in teaching afterwards that is the handicap in bringing more Ph.D.'s into teaching engineering?

Dr. NORDBY. I suppose, to a certain degree. Most of the studies indicate that in order to keep somebody in graduate school, you would have to give him a fellowship or a stipend that is about half of what their entering job salary would be. Now, that has changed significantly. We have not raised our graduate stipends—we have been unable to—so they are a lot less than that. Some institutions have come up, let's say, to the $16,000 level. But you do have to support yourself through that period, and it can be a lengthy period of, let's say, 4 years to do it. Salaries are so good in industry that I don't think they will take that challenge as often as they once did.

Mr. SLAUGHTER. That is all I have, Mr. Chairman.

Mr. FUQUA. Mr. Reid.

Mr. REID. Mr. Chairman, I don't have any questions.

Mr. FUQUA. Dr. Nordby, you emphasized design, and the recent initiatives by the Federal Government, more particularly the NSF, have emphasized engineering research. Can or should that program be broadened to include things other than research, such as design?

Dr. NORDBY. In engineering, we kind of combine the two in our thinking because we do applied science, and so we regard them about equal and the same. In fact, research in universities is often along the design lines. On the other hand, it is often very basic in approaching the science. I think the key is creativity and innovation, and that can take place either through design or research.

Mr. FUQUA. Well, in the new inventions that are coming along such as computer-aided design and manufacturing, CAD/CAM, is that going to enable us to be able to reduce the number of bachelor's-degree engineers?

Dr. NORDBY. I don't think so. I think there is going to be an increasing need. On the other hand, the use of CAD or CAD/CAM—all of those acronyms—when they get developed, they are mostly run by technicians. Now, a draftsman, I know, can, over a period of 2 years, become, let's say, four times as productive in the drafting process, some say as much as eight times, so there is a saving there. I frankly believe engineering firms or engineering companies that aren't completely computerized in the CAD/CAM type of computerization will not be able to compete in 5 years, and maybe most of them cannot now if they don't have some element of it. It is a matter of productivity in the marketplace, I think.

Mr. FUQUA. Ms. Vetter, how are the projections affected by the long-term population trends or demographic trends—births, immigration, shifts to the Sun Belt—how are they affected?

Ms. VETTER. Certainly we will have fewer students, and we already are beginning into the period of fewer students in the college-age population.

Students still tend to choose majors in approximately the same field, proportionally, that they have for the last 50, 60 years. There are some shifts up and down. There is a very remarkably consistent 20 to 22 percent of all students who choose, at the baccalaureate level, to major in science or engineering, but they switch in and out of physics, which was very popular for many years and then became very horrible because there were no jobs in physics, and now enrollments are starting up again in physics. Most of those physicists who came out in that period are now in the engineering population, because there were no jobs in physics, but the physics and engineering training have many similarities, obviously. The present demand, over the last few years the emphasis has been in engineering, so students have been going out of chemistry, out of biology, out of all the areas and into engineering.

The next time engineering hits a snag—and it will—the supply/demand curves are like sine waves that are out of kilter with each other, and when they get too far out of kilter, suddenly you will have—and because it is unusual, it will be front page news—you will have an engineer out driving a cab in New York City who will pick up a reporter from the New York Times who will write a front page story about engineers are now driving cabs, and freshman engineering enrollment will drop 20 percent the following year. [Laughter.]

Mr. FUQUA. Is that an accurate prediction? [Laughter.]

Ms. VETTER. It has happened twice, at least, because students always react to today's marketplace rather than the one that they will affect, or can be affected by, because they cannot foresee that one, and none of us can, but we try to show them that.

But kids will still tend to major in the same general areas. Biology has been losing because, finally, kids caught onto the fact that a bachelor's degree in biology is the new liberal arts degree. It didn't offer any kind of a job in biology, and then they decided, all right, I just have to go on and get a Ph.D. What they didn't know all this time was that we had a lot of Ph.D.'s sitting out there who couldn't find a job either, and who, each one of them thinks, "Gee, there is something wrong with me." But it is because we don't have any good data in the biological sciences.

Mr. FUQUA. How about bioengineering, which is becoming very much in the forefront?

Ms. VETTER. Bioengineering is a very tiny field, again one for which we have almost no data because it is little. But I certainly don't know of any bioengineers who have any difficulty finding a job, because indeed, I think we are into a period of new kinds of prosthetic devices, of ways of helping the handicapped, who are an increasing proportion of our population, and particularly who become handicapped later, not the ones who start off handicapped.

So, yes, there is a demand for these. There is a great demand for some of these subfields within the life sciences. There are shortages. But we are not really sure which ones they are in because we don't have any data. We do know that a general Ph.D. in biology is a good ticket to oblivion right now.

Mr. **Fuqua**. Mr. Slaughter mentioned chart L, and I was observing that on the average SAT scores in math, they have continued to increase moderately since 1970. Is that an indication that our high schools are doing a good job in teaching math?

Dr. **Reyes-Guerra**. I would not attribute it to that. I attribute it to the fact that the number of applicants, the pool of applicants to the schools of engineering has increased, and consequently——

Mr. **Fuqua**. Competition is more keen?

Dr. **Reyes-Guerra**. Yes. But in general, no, I do not think they are doing much better. I think the previous remarks, like the remarks of Dr. Berryman and others, as to the need to start early in nurturing young people to take science and math, this is very necessary because otherwise they close the doors, and this data sort of shows that.

I would like, also, referring to that data, to point out that between 1970 and 1975, there was a decrease in enrollment in engineering, really, proportional to the rest, which sort of supports what Ms. Vetter said concerning the fact that the bad news was out there, and that was the time when the Boeing problems were out in Seattle, Washington. So the interest was lacking.

However, when you really analyze those unemployed engineers who were pumping gas, as portrayed in *Life* magazine and others in most cases they were people were in two-career families who did not want to move from the area. I think, in general, engineers in the fifties were more mobile than they are now. Now, with the new pressures of family, moving from one part of the country to another to accept a position is difficult if you have a two-career family.

I do not agree with Ms. Vetter that there will be a time when I see a lot of unemployment of engineers. As long as we continue to be a technologically literate group who comes out of the colleges, industry, whether it is the financial industry or any other industry, will keep on taking these young men and women and putting them into functions where they will use their technology.

There is a lot of evidence of that in New York City, where we see so many of them are the only ones coming out, even out of schools of economics, with knowledge as to how to handle a computer, and they are being taken up by the stockbrokers and other financial institutions simply because of that ability, at a very high salary, even higher than they would get as engineers. It is just to attract that knowledge that the schools have imparted on them of technology.

Ms. **Vetter**. I would like to let the record indicate a correction of something that was said. It is not that engineering unemployment will be high; it is that engineering unemployment of 2½ percent creates front-page stories because it is so unusual. It is not that it will ever get high. It is higher sometimes that it is other times.

Right now the engineering unemployment rate is probably about 0.8 percent. When it gets up to 2 percent, that is a tremendous increase, but compared with unemployment rates for other groups, it is very low, and I don't ever expect it to get up in the 5 percent, 6 percent ranges.

But it is the fact that it is different. When it gets up that high, even to 2 percent, then it is front-page news, because, indeed, it is something that is different.

Mr. **Fuqua**. Would you comment on the SAT scores?

Ms. **Vetter**. Oh, I think the SAT scores dropped nationwide. There are many, many theories, of course, as to why that happened, and probably all of them played some part. One of them certainly was the loss of rigidity of requirements in what students had to learn and take in school. I think there is no question about that.

One of the more recent theories is that it has strictly to do with the size of families, that this was the period in which there were more children to a family, and the IQ will drop for all kids with larger size families, and that as family size is now dropping, you will see the IQ go up and the SAT scores go up, and there is some—certainly you can show that this has been true in past periods. Whether that is a cause and effect, I do not know.

The SAT scores were terrible in 1975. They were bad almost all over. The kids who go into engineering and into most of the sciences are, however—that is one of the problems. They are from the better high schools, with the better teachers, who get the better quality of education, and that is why the score changes are not more drastic than they are.

It is the children from the schools that are in the deprived areas, whether they be—and sometimes they are—urban schools; sometimes they are country schools, where these students do not have the options and opportunities. Their scores are low enough to bring down national averages everywhere. But, also, those kids don't get into engineering. Most of them don't even try.

Mr. **Fuqua**. Thank you all very much for sharing with us this morning.

Ms. **Vetter**. You are very welcome.

Mr. **Fuqua**. The task force will meet again tomorrow morning at 10:30 in room 2325.

The meeting is adjourned.

[Whereupon, at 11:36 a.m., the task force recessed, to reconvene at 10 a.m., the following day, Thursday, July 25, 1985.]

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SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

THURSDAY, JULY 25, 1985

House of Representatives,
Committee on Science and Technology,
Task Force on Science Policy,
Washington, DC.

The task force met, pursuant to recess, at 10:38 a.m., in room 2325, Rayburn House Office Building, Hon. Don Fuqua (chairman of the task force) presiding.

Mr. Fuqua. Good morning. I would like to welcome you to the sixth and final day of hearings on "Scientists and Engineers: Supply and Demand."

As you are aware, these hearings are a part of our larger study of the U.S. science policy being done by this special task force of the Committee on Science and Technology.

Our hearings today consist of two panels. The first has only one witness and will be devoted to addressing the issue of professional responsibility. This issue becomes of concern to us as our country moves more into areas of high technology, because future scientists and engineers will be assuming decisionmaking positions for which typically they are not specifically trained. Yet their decisions and activities will impact more and more on social, economic, political, and ethical issues.

Our final panel will present an overview of the future supply and demand of scientists and engineers. This diverse panel will attempt to isolate the essential issues surrounding the supply and demand for scientists and engineers in order to arrive at the pertinent questions which the task force must ultimately answer.

Because we have two panels this morning, I will ask each witness to be brief in order to leave time for questions from the task force members.

Let me now call our first witness, Dr. Walter Lynn of Cornell University. Dr. Lynn, we are very pleased to have you with us this morning.

[A biographical sketch of Dr. Lynn follows:]

Dr. Walter R. Lynn

Walter R. Lynn is a Professor of Civil and Environmental Engineering and Director of the Program on Science, Technology and Society at Cornell University.

His teaching and research areas of interest are environmental systems analysis, water resources and public health, and engineering and science policy.

He has been a member of the Cornell faculty since 1961 and has served as Director of the School of Civil and Environmental Engineering, Director of the Center for

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Environmental Research, and as a Member of the Cornell University Board of Trustees.

Lynn holds a bachelor's degree in civil engineering from the University of Miami, a master's degree in sanitary engineering from the University of North Carolina, and the Ph.D. in systems analysis and civil engineering from Northwestern University. He is a Registered Professional Engineer in New York State and a Registered Land Surveyor in Florida.

Apart from teaching and research his experience includes employment as a civil and sanitary engineer, Director of Research for the Ralph B. Carter Company, and consulting civil engineering practice.

He is active in a number of professional societies. Among his current activities are: Member of Board on Water Science and Technology, and the Panel on Energy, Environment and Resources of the Engineering Research Board of the National Research Council, NAS/NAE; and Associate Editor, *Journal of Environmental Economic and Management*.

STATEMENT OF DR. WALTER R. LYNN, PROFESSOR OF CIVIL AND ENVIRONMENTAL ENGINEERING, AND DIRECTOR, PROGRAM ON SCIENCE, TECHNOLOGY AND SOCIETY, CORNELL UNIVERSITY, ITHACA, NY

Dr. LYNN. Mr. Chairman, I am delighted to be here.

I am indeed pleased to have this opportunity to discuss what universities do, or better yet, what ought to be done, in preparing students to deal with some of the ethical and value questions which arise in scientific and engineering contexts.

Let me explain, first of all, I am not a philosopher; I am an engineer by training, a registered professional engineer in New York State, and I currently chair the Water Science and Technology Board of the National Academies. I also, fortunately, have an opportunity to direct the Cornell Program on Science, Technology, and Society at Ithaca.

Now, it is true that we would trivialize the complexity of our society and the science and engineering endeavors if we were to characterize science as an activity which is solely concerned with improving and expanding our understanding of nature and engineering, as an activity which employs or applies such knowledge for useful purposes. While such terse statements are informative, they really don't help us to understand the variety of roles played by those who do science and engineering, or how scientists and engineers fill these roles.

As you all know, science and engineering involve sizable numbers of people. Accordingly, NSF reports that in 1983 there were almost 3.5 million people categorizing themselves as scientists and engineers, employed by business and industry as the principal employer; Government, the second principal employer; and educational institutions, the third. These people perform a variety of different kinds of duties, including management; development; production; reporting, statistical and computing; basic and applied research, which only involves about 10 percent of that community; and teaching, which is about 7 percent of that population.

Now, the employers of engineers and scientists and the kinds of work they perform, in large part, define the role of the players, namely the players being the scientists and engineers. Society expects, and has a right to expect, certain kinds of behavior from those of us who perform roles in the context of science and engineering.

The basic assumptions that must guide the professions of science and engineering are: that truth and knowledge will be derived from research efforts that are conducted with honesty and fidelity; that knowledge will be openly and fully transmitted to present and future generations; and that such activities will lead to improvements in the lives of individuals and will help protect them from harm. Fraud, plagiarized information, stolen ideas, falsified data, and unwillingness to share data or information are examples of behavior which ought to be of concern to members of the science/engineering community—and are, in a large degree—as well as the general public.

Now, according to the standards of ordinary morality, all individuals are held accountable for their behavior. This applies to all persons regardless of their position, profession, or occupation.

What is sometimes called role morality is an addition to ordinary morality. The acquisition of specialized skills and knowledge required to enter the most highly skilled occupations and professions carries special responsibilities and burdens not borne by ordinary citizens. Scientists, engineers, and technicians acquire rights, special duties, to behave in ways required by the special roles they fulfill in society, that is, role morality. That is obviously true of Members of Congress, of public officials. We all occupying these special positions do have a role morality in addition to ordinary morality.

Moral issues concerning the development and use of science and technology pervade every aspect of human activity, and most of the "goods" and "bads" which we meet in ordinary life are a direct consequence of knowledge acquired and techniques developed within the last three or four decades.

Members of scientific and engineering communities take great pride in those advances which improve the human condition—in medicine, transportation, agriculture, communications, et cetera. However, many of us have recently become increasingly aware of and sensitive to the possible negative consequences of these achievements.

During the last decade, the public has become increasingly concerned and apprehensive about safety and risk associated with a variety of activities resulting from scientific and engineering activities. Pesticides, genetically-engineered organisms, disposal of nuclear wastes, dams, nuclear power, toxic effects of chemicals, and Star Wars are but a sampling of a variety of subjects which appear on the horizon and about which the public has some concern, and frequently legitimate concern. .These are but a few examples, and I am sure we could all generate more.

Now, should the scientists and engineers be aware of the risks and hazards associated with the outcomes of their work, and should such matters influence how, as professionals, they conduct themselves and their affairs? It has been argued that such concerns are not the business of scientists and engineers but should be left to those who better understand political and social issues. But it is not clear who those other people would be and how much of the technical aspects they would know. Clearly, if role morality has any meaning in the context of science and engineering, we scientists and engineers cannot divest ourselves of that responsibility for actions involving ourselves.

Some suggest that the only aspect of risk and safety which should concern scientists and engineers is the measurement of the threat—so-called risk assessment. It is often erroneously assumed that risk assessment is an objective, value-free exercise, separate from something called risk management. That, however, is not the case, since choosing what to measure, or what ought to be emphasized in determining risk or interpreting what risk and safety mean are not value-free exercises.

If one agrees that scientists and engineers have ethical responsibilities for social and political consequences of their actions, it follows that they must understand the nature of the moral dilemmas posed and must develop the skills required to analyze and evaluate possible outcomes.

Engineering societies have had a long and tortuous history of concern with the ethics of their profession, and the science and academic communities have been, while less explicit, beginning to articulate their ethical responsibilities. These matters have been of principal concern to those engineers who act as consultants, but of late more attention is being given to the ethical problems faced by engineering employees. The Center for the Study of Ethics in the Professions at the University of Illinois has been a very active and prominent group attempting to draw more attention to this topic, and its efforts have been supported in the past by grants from the National Science Foundation and the National Endowment for the Humanities.

A number of universities have begun to examine their own records and rules for maintaining high ethical practices in scholarship and research. Needless to say, high standards are essential in academic life, since the universities play a key role in educating fledgling scientists and engineers in their disciplines and in their ethical responsibilities.

This year Cornell University will initiate a new program entitled "Reason, Social Values and Policy" which has as its objectives, and I quote:

> To integrate more vigorously humanistic and ethical concerns with professional training. Insularity and specialization of the disciplines and professions endanger not only the educational mission of Cornell University; these attitudes endanger the very functioning of our democratic society, in which the responsibilities of citizenship and the forging of public policy must be carried out by citizens who are capable of participating in rational discourse on technological issues, and who are also competent to deal with the intrinsic social and ethical questions.

Now, efforts to address ethical standards and concerns are also being carried out by other academic institutions. I don't mean to suggest Cornell is the only one. A very important supporter of some of these initiatives has been the NSF Program on Ethics and Values in Science and Technology, called EVIST, which began in the midseventies, largely at the instigation of NSF staff members. The objectives of the EVIST Program are:

> To stimulate research on ethical implications and value assumptions in the role of science and technology in American society; and to improve discussion and understanding of those roles and of policies and practices affecting and affected by science and technology.

Working with a very modest budget, EVIST has given invaluable support to many new programs and research efforts that emphasize high ethical standards. Last spring, as some of you know, many of us were shocked to learn that EVIST was scheduled to be eliminated, for reasons that are not yet clear to me. Fortunately, in my view, wisdom prevailed, and at the last hour the EVIST Program was continued in the 1986 budget.

I believe this committee has a special responsibility to nurture and protect this program within NSF. Its very existence gives special credibility, visibility, and importance to the topics which come under its purview. If anything, this activity deserves greater support from the Foundation than it now receives, since its activities deal with the very essence of science and engineering endeavors. Without your active intervention—that is, the committee's intervention—many of us believe that this activity will disappear.

I appreciate your attention, and I want to acknowledge a colleague of mine, Stewart Brown, who is a philosopher who was very helpful with me in presenting this statement. I will be pleased to respond to any questions you may have, Mr. Chairman.

[The prepared statement of Dr. Lynn follows:]

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. House of Representatives
Rayburn Building, Room 2325
July 25, 1985

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Walter R. Lynn
Program on Science, Technology & Society
632 Clark Hall, Cornell University
Ithaca, New York 14853

Mr. Chairman, Members of the Committee:

I am pleased to have this opportunity to discuss what universities do (or ought to do) to prepare students to deal with some of the ethical and value problems which arise in scientific and engineering contexts.

My name is Walter R. Lynn. I am a Professor of Civil and Environmental Engineering at Cornell University and Director of the Cornell Program on Science, Technology and Society. I recently completed a three-year term as Chairman of the Water Science and Technology Board of the NAS/NAE and am a Registered Professional Engineer in New York.

We would trivialize the complexity of our society and these endeavors if we were to characterize science as an activity which is solely concerned with improving and expanding our understanding of nature, and engineering as activity which employs or applies such knowledge for useful purposes. While such terse statements are informative, they do not help us to understand the variety of roles played by those who do science and engineering, or how scientists and engineers fill these roles.

Science and engineering involve sizeable numbers of people. NSF reports that in 1983 there were almost 3.5 million working scientists and engineers. These individuals were employed primarily by Business and Industry (67%), Government (14%) and Educational Institutions (12%). The kinds of work they perform include: Management (25%), Development (21%), Production (13%), Reporting/Statistical Analysis/Computing (10%), Basic and Applied Research (10%), and Teaching (7%).

The employers of scientists and engineers and the kind of work they perform, in large part, define the roles of the players. Society expects and has a right to expect certain kinds of behavior from those of us who perform roles in the context of science and engineering.

The basic assumptions that must guide the professions of science and engineering are: that truth and knowledge will be derived from research efforts that are conducted with honesty and fidelity, that knowledge will be openly and fully transmitted to present and future generations, and that such activities will lead to improvements in the lives of individuals and will help protect them from harm. Fraud, plagiarized information, stolen ideas, falsified data, and unwillingness to share data or information are examples of behavior which ought to be of concern to members of the science/engineering community as well as the general public.

According to "standards" of ordinary morality all individuals are held accountable for their behavior. This applies to all persons regardless of their position, profession or occupation.

What is sometimes called role morality is an addition to ordinary morality. The acquisition of specialized skills and knowledge required to enter most of the highly skilled occupations and professions carries special responsibilities and burdens not borne by ordinary citizens. Scientists, engineers and technicians acquire special rights and simultaneously special duties to behave in ways required by the special roles they fulfill in society -- i.e, role morality.

Moral issues concerning the development and use of science and technology pervade every aspect of human activity. Most of the major "goods and bads" which we meet in ordinary life are a direct consequence of knowledge acquired and techniques developed within the last three or four decades.

Members of the scientific and engineering communities take great pride in those advances which improve the human condition -- in medicine, transportation, agriculture, communications, etc. However, many of us have recently become increasingly aware of and sensitive to the possible negative consequences of these achievements.

During the last decade the public has become increasingly concerned and apprehensive about safety and risk associated with a variety of activities resulting from scientific and engineering activities. Pesticides, genetically engineered organisms, disposal of nuclear wastes, dams, nuclear power, toxic effects of chemicals, "star wars": these are but a few examples of issues about which there is widespread and justifiable public concern and uncertainty among scientists.

Should scientists and engineers be aware of the risks and hazards associated with the outcomes of their work, and should such matters influence how as professionals they conduct themselves and their affairs? It has been argued that such concerns are not the business of scientists and engineers but should be left to those who better understand political and social issues. But it is not clear who these others would be and how much of the technical aspects they would know. If role morality has meaning, scientists and engineers cannot divest themselves of responsibility for their actions.

Some suggest that the only aspect of risk and safety which should concern scientists and engineers is the measurement of the threat -- risk assessment. It is often erroneously assumed that risk assessment is an objective, value-free exercise that is separable from "risk management." That, however, is not the case, since choosing what to measure, or what ought to be emphasized in determining risk or interpreting what risk and safety mean are not value-free exercises.

If one agrees that scientists and engineers have ethical responsibilities for the social and political consequences of their activities, it follows that they must understand the nature of the moral dilemmas posed and must develop the skills required to analyze and evaluate possible outcomes.

While the engineering societies have had a long and tortuous history of concern with the ethics of their profession the science and academic communities have been less explicit in articulating their ethical responsibilities. These matters have been of principal concern to those engineers who act as consultants, but of late much more attention is being given to the ethical problems faced by engineering employees. The Center for the Study of Ethics in the Professions at the Illinois University of Technology has played a prominent and distinguished role in studies and analyses of and techniques for teaching engineering ethics. Their efforts have been supported in the past by grants from the NSF and the NEH.

A number of universities have begun to reexamine their own record and rules for maintaining high ethical practices in scholarship and research. Needless to say, high standards are essential in academic life, since the universities play a key role in educating fledgling scientists and engineers in their disciplines and in their ethical responsibilities.

This year Cornell University will initiate a new program on Reason, Social Values and Policy which addresses these matters. To quote their statement of objectives:

> Our goal is to integrate more vigorously humanistic and ethical concerns with professional training. Insularity and specialization of the disciplines and professions endanger not only the educational mission of Cornell University; these attitudes endanger the very functioning of our democratic society, in which the responsibilities of citizenship and the forging of public policy must be carried out by citizens who are capable of participating in rational discourse on technological issues, and who are also competent to deal with the intrinsic social and ethical questions.

Efforts to address ethical standards and concerns are also being carried out at other academic institutions. A very important supporter of these initiatives is the NSF Program on Ethics and Values in Science and Technology (EVIST) which began in the mid-seventies largely at the instigation of NSF staff members. The objectives of the EVIST program are "to stimulate research on ethical implications and value assumptions in the role of science and technology in American Society; and to improve discussion and understanding of those roles and of policies and practices affecting and affected by science and technology."

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I appreciated your attention and would be pleased to respond to any questions you may have.

DISCUSSION

Mr. **Fuqua**. Thank you very much, Dr. Lynn.

You touched on this issue, and I was at a speech earlier this year down at the National Academy of Sciences when the Secretary of State, George Shultz, addressed the group there and made a comment that scientists should limit their comments to science and stay out of politics.

Scientists do sometimes presume to be experts outside of their own field, or maybe beyond science. Do you think this is an appropriate role? Certainly we don't get involved in censorship in this country. People are able to express themselves. But maybe sometimes we get out—or do we get out of our fields when we start looking for expert advice in areas that maybe we are not as familiar with?

Dr. **Lynn**. Mr. Chairman, my comment which I made in my testimony was drawn from reading the press release given by Secretary Shultz at the academy presentation.

One of the difficulties is that, frequently, if ideas are not viewed popularly in the political process, those who would oppose it are in fact not considered to be kind or supportive individuals, obviously.

As I recall, the Secretary's comments had to do with scientists using their credibility in science and objecting to the fact that that was flowing into areas in which they had no special expertise.

But the problem is, I don't know who has—and I think his phrase was "moral and political issues"—and the question of whether expertise involving politics in its best sense and moral issues is reflected by others in the Government and more so than are scientists and engineers, I find to be of questionable validity.

I don't support the Secretary's position. I think the debate is sharpened and enhanced by having more of the scientific community involved in issues which do have technical components. Technology and science just don't terminate at a door in which we say, well, that's the end of the science and technological input, and the rest of it belongs in a totally different arena.

Mr. **Fuqua**. On another facet, what are the limits of the applicability of peer review?

Dr. **Lynn**. Peer review is complicated. There has been so much written about peer review and research criteria. I am not sure that I can add anything to that debate at this time, any new information to that question at this point, sir.

Mr. **Fuqua**. Courses on professional responsibility have been introduced into the engineering curricula of a number of institutions. Do you think similar types of courses are appropriate to curricula in all the other areas of sciences?

Dr. **Lynn**. Absolutely, absolutely. For the past 12 years, I have been teaching a course to graduate engineers entitled "Professional Practices," in which a large part of that course deals with the kinds of ethical dilemmas that arise in engineering practice.

Let me point out that there is concern about that in which the question is, shall I, as an individual, project my own ethical values on students? My argument is that that is not necessary. What is needed is to, if you will, destroy the innocence that many youngsters have that such questions ever arise or that they are aware of those kinds of questions.

What is needed is to provide students with a means to analyze and dissect these problems. In my teaching efforts, I make no effort to judge how they would resolve the issue—in other words, what conclusion they draw—but that there is a methodology provided to us by the philosophical community that says, "Look, you can do a detailed analysis to defend or to rationalize your position."

Mr. **Fuqua**. Mr. Packard.

Mr. **Packard**. I did not attend the meeting where Mr. Shultz made the comment that was reported to have been made, but when it comes to ethics, values, and morality, that is always a sensitive subject to some people who feel that it ought to be left to certain areas like religion or ethics or sociologists and so forth.

In my judgment—and, of course, I think that your comments and your testimony are very interesting in this area—I think every agency, every field, ought to emphasize morality and ethics and values. We have tended to relegate that to specific areas and say, "Don't get into that territory; don't touch those areas because those are very personal and ought to be determined on a personal basis."

Even in our families, we have often tried to convey the concept that parents would be ill-advised to impose their values on their children. I think that concept has been to the detriment of our society, myself. I think that those are areas that are basic to the protection of our society. Do you feel the same?

Dr. **Lynn**. I think the topic needs a lot of attention. I am less sensitive about you dealing with your children or me dealing with mine, but as a teacher, the question of what are the right values to have is always an interesting and complicated question.

Therefore, as a teacher, my responsibility is to ensure that my students are in fact prepared to deal with these kinds of problems and not pretend that they do not exist; that is, the kinds of ethical dilemmas which arise in the course of doing work. Let's simply take, for instance—science is part of the discussion here—the business of plagiarism. Plagiarism is unethical; it is immoral; it is a form of stealing.

Now, there is a very fine line between what one quotes from an article and gives due credit for. It can be done innocently; it can be done maliciously. Why is that bad is a question that it seems to me the science and engineering community ought to make sure students understand, because, after all, there it is in the book, and it is detached; it does not involve a direct relationship between themselves and another individual; it is very indirect.

The sense of importance as to why that degree of honesty is of value can certainly be rationalized without someone saying, "Look, I tell you that cheating is bad." That is the concern, and where we might differ, when we get outside of our own families, is setting forth a set of moral and ethical standards for everyone that sort of becomes an obligation for those individuals. I think it is a rational process; that is what I am saying.

Mr. **Packard**. In the classroom, who is best qualified to determine what values ought to be protected and taught and emphasized, and how? Is that a dilemma with the educational system in terms of to what extent instructors, professors, ought to get involved in identifying value systems?

Dr. LYNN. I think most of my colleagues would be somewhat apprehensive about these kinds of questions, mainly because they feel unprepared to teach them. For example, if I teach a course on differential equations, I know how to do that, and it is fairly standard, and I can write the mathematics on the board, and it has a degree of objectivity which is straightforward and justifiable.

Now, when I go to shift gears and talk about how well do you use mathematical models to help somebody make a decision about doing something in which I know the model, as a mathematical exercise, is incomplete, how strong an advocate shall I be to get somebody to use this kind of device to take a public policy or private action? Well, that then becomes a value question of both the value of the advice and the like.

Now, faculty members who are not trained in that area suffer not from an unwillingness to deal with the problem but suffer from how do I do this responsibly as an academic. I think many academics worry about projecting their own personal, private values on students, except in a professional context. And there is agreement—I tried to list—we all believe that providing false data is irresponsible for the science community; plagiarism is irresponsible; providing advice without qualifying it when your values are included that transcend the information you have.

Where I think Secretary Shultz argues is that we go beyond our technical expertise to impose our political, our moral values on this process. I think one has to be able to declare that and separate those things. So the discomfort is the skill in being able to do the pedagogy for people in the science community.

Mr. PACKARD. It appears to me that we are in a time now when the lack of integrity and ethical practices is perhaps at least more obvious and perhaps more prevalent than ever before in our scientific world. It stretches over into—perhaps not into, but beyond—the scientific portion of their world, but many of our large procurement companies that are dealing in high technology with Government contracts and so forth are struggling now with integrity within their company, within their hierarchy, within their procedures. That obviously would accentuate the need for some kind of ethical and value judgment training or discussions at the educational level.

Do you see a correlation between the lack of that in the past in the classrooms in our colleges and universities and at the secondary levels and the problems that we are struggling with now in our scientific and high technology world?

Dr. LYNN. I don't have any data. I tend to support your view, but I do that more on speculation than I do having any concrete evidence.

I think that academic institutions—and let me speak to the universities, where I have far more experience—really do have an obligation to do that. That is part of what is called general education as well as the specialty education.

The point I have tried to make today is that there are special problems that arise to those of us who hold these special positions called scientists and engineers which give us additional responsibil-

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ities. For those who are troubled, where greed becomes a compromiser of their own integrity and their willingness to honor a public trust, if that is a problem, I don't think education would have made any difference in that regard.

But there are more subtle and also very significant things that go on in these positional fields which create a special kind of public trust, and I think that requires a great deal of attention. I think it is also part of what I call general education.

I would be remiss to say that it doesn't go on. There are lots of forces in this society, as I am sure you know, that encourage people to not address their own values, frequently, and to suppress their instincts about ethical behavior, and I am not sure any academic institution can correct that problem.

Mr. Packard. Thank you, Mr. Chairman.

Mr. Fuqua. Mr. Slaughter.

Mr. Slaughter. No questions, Mr. Chairman.

Mr. Fuqua. Mr. Reid.

Mr. Reid. I have no questions, Mr. Chairman.

Mr. Fuqua. Dr. Lynn, thank you very much for joining us this morning.

Dr. Lynn. Indeed, sir. Thank you.

Mr. Fuqua. We appreciate your being with us.

PANEL

Our next panel will be Dr. Simon Ramo of TRW, Inc.; Dr. Michael Nacht, University of Maryland; and Dr. Charlotte Kuh, business research at American Telephone and Telegraph.

Dr. Ramo, we are very delighted to have you with us today, and thank you for sharing your wisdom with us this morning.

[A biographical sketch of Dr. Ramo follows:]

Dr. Simon Ramo

Dr. Ramo, holder of the Presidential Medal of Freedom, the Nation's highest civilian award, is a co-founder and the "R" of TRW, Inc., one of the world's largest technological corporations. The Chief Scientist in the development of the U.S. intercontinental ballistic missile capability, Dr. Ramo was chairman of President Ford's Committee on Science and Technology and of President Reagan's Transition Task Force on Science and Technology. He has been a member of the Advisory Council to the Secretary of State on Science and Foreign Affairs and The White House Council on Energy Research and Development and is now a member of the National Science Board. He is a trustee and visiting professor at the California Institute of Technology and has been a Regents' Lecturer of the University of California and a Fellow of the Faculty at the Kennedy School of Government, Harvard University. He has received the top national science recognition, the National Medal of Science, and is the recipient of the National Academy of Engineering's award for contributions to national policy on science and technology. Dr. Ramo is the author of several textbooks in science, engineering and management widely used by universities and practitioners throughout the world.

STATEMENT OF DR. SIMON RAMO, COFOUNDER, TRW, INC., REDONDO BEACH, CA

Dr. Ramo. Mr. Chairman, I am very happy to be here to present the following testimony, which frankly expresses a very strong conviction that, as a nation, we have been severely underinvesting in the long-term strength of our science and engineering. That shortcoming has many dimensions. I shall comment on several of them, starting with one concerning which you, Mr. Chairman, have recently been quoted as follows:

> The condition of research facilities at colleges and universities is a critical issue affecting the future of our Nation. We cannot allow the current state of decline to continue. Strong and effective action, similar in nature to the U.S. response to the launching of Sputnik, must start immediately. According to current estimates, one-half of the physical plant of all universities and colleges is more than 25 years old, and one-quarter of it was built prior to World War II. It is in our university laboratories that much of the pioneering work of American science is carried out. These facilities function not only as places where we expand our scientific frontiers, but also as centers where we educate future scientists and engineers.

These very succinct sentences state my views on one important facet of the subject under examination by the task force today. Perhaps the chairman has issued equally well-stated comments covering the other critical aspects of our national failure to ensure the long-term science and technology status of our country. If so, I have not happened to run across them, so I shall attempt to phrase some paragraphs of my own on some of those other points.

In Japan, of every 1,000 college graduates, 40 obtain their degrees in engineering. In America, the figure is seven. Only 100,000 American high school graduates are exposed to calculus, usually for only a part of 1 year. In the Soviet Union, 5 million students take 2 years of calculus. Half of our high schools rely on mathematics and science instructors who are not licensed to teach and are only temporary instructors. Less than half of our high school graduates have had a full year of science and only 10 percent receive instruction in physics. Laboratories are disappearing from American high schools so that the exposure to physics, chemistry or biology is often superficial.

The Nation today has less physicists than it had in the 1970's. The number of U.S. citizens receiving doctoral degrees annually in science and engineering, an important indicator of our future strength, instead of rising to meet the needs of a steadily more technological Nation, is 15 percent lower than in 1971. Half of the Ph.D.'s awarded in engineering in the United States this spring were to foreign citizens, and the engineering doctorates granted U.S. citizens has declined 48 percent since the beginning of the 1970's. In fact, if it were not for the foreigners doing graduate work in the United States, we would not have enough instructors to teach science and engineering to our undergraduates. Foreign citizens account for between 40 to 60 percent of the doctoral students enrolled in programs in emerging areas—biotechnology, computers, manufacturing technology, materials, microelectronics, and robotics.

In our engineering schools, not only is the equipment out of date and deteriorating from old age, but we are barely equipped with staff to teach real-life engineering. Our engineering schools largely can provide only the mathematics and science underlying engineering. Of course, we do not expect a university program to be all-sufficient, and we know that professional skills are developed mainly after graduation, in actual practice in the company of seasoned professionals. Most of our engineering schools, however, do not provide their students with the important minimum feel for engineering as constituting the practical application of science and technology to achieve benefits for the society. Engineering students rarely come to appreciate early that the design of a product requires it be manufacturable in a cost-effective way and reliable and maintainable when it is put to use, and that the product's characteristics and performance must match the market demand for it, and that the return on the investment required to develop the product must be competitive with other uses of capital. To imbue students with these principles requires faculties whose backgrounds combine expertise in the underlying intellectual disciplines with considerable experience in engineering practice. Universities are hard pressed to attract such individuals in competition with industry, whose salaries are much higher and reflect the growing shortage of requisite engineering talent in the United States.

If the programs for filling our Nation's future requirements for engineers and scientists are not broadened, America's technology leadership will suffer severe erosion. That impairment is already under way. The United States probably will remain for decades the leader in the world's science and technology olympics, which is to say we will win in total points over any single other nation. But our rivalry is not with any one nation, except perhaps in the national security field against the Soviet Union. We are competing instead against the entire rest of the world. Every other nation has judged technology advance to be the basic means for achieving national security, economic growth, and increased standard of living and is avidly engaged in building up its technological resources. In contrast, we have been laying the groundwork for our possessing a decreasing fraction of all of the world's scientists and engineers.

In the last few decades we have gone from having about half of the well-supported engineers in the non-Communist world to a third. In another decade, we shall possess only a fourth. Other developed nations now are able to put about as much in resources behind each engineer or scientist as are we. This means then in 10 or 20 years, the majority of all technological breakthroughs and improvements in production and performance of technological products will originate elsewhere. The U.S. Patent Office used to award very few to foreigners, and the number of patents to Americans increased every year. In 1983—that is the last year when we had full statistics—foreign-origin patents constituted 42 percent of the total U.S. patents, while the annual number granted to Americans has declined by over 40 percent in the last 15 years. Often we hear concern expressed that in the past we allowed our technological leads to be picked up too readily by other countries. It may be that we should now devote more attention to inventing how we might obtain for our use in a timely and economic fashion the technology advances that are more likely to originate outside our country.

The trend I have been describing has been evident for many years. On assuming office, President Ford was troubled because the White House had no science presence on its staff—the old Office of Science and Technology having been abolished by President Nixon—and asked me to chair a task force to assist in planning the reestablishing of an appropriate office. The task force did that by listing the critical issues that deserved high-level Government attention and that involved science and technology deeply. American's lack of priority for the arranging of an adequate supply of scientists and engineers for the future was high on that list.

In 1976, I was appointed chairman of the President's Science and Technology Committee, a post set up by the same congressional legislation that created the Office of Science and Technology Policy. In the initial meetings of this committee, we again called attention to the insufficient existing support for the adequate generation of scientists and engineers to maintain America's lead either as regards national security or international competition in civilian technology.

In 1980, I found myself chairman of the Transition Task Force on Science and Technology for the incoming Reagan administration. Again we expressed strong concern about our national failure to invest adequately to guarantee America's future supply of engineers and scientists.

Recently, I became a member of the National Science Board, which oversees the activities of the National Science Foundation. The National Science Foundation's charter, as the members of this committee know, includes responsibilities with regard to education at all levels in science, mathematics, and engineering. The committee also is aware, however, that the past pattern of the National Science Foundation has been primarily to foster scientific research at the universities. Relatively speaking, there has been very little attention to engineering education, to undergraduate education in science, and even less to education in science and mathematics in the primary and secondary schools.

In the last 2 years, it is important to note, this situation has been improving. Influential Members of Congress, some agencies of the executive branch, the White House Office of Science and Technology Policy in particular, and the National Science Foundation itself have begun to react to the increasing alarm about future deficiencies. The result has been to launch new and well-thought-out programs dealing with engineering education, undergraduate education in science, and even means to improve the understanding and appreciation of science and mathematics among young people of primary and secondary school age. But these programs are still modest Indeed, the funding hardly allows for more than embryonic programs.

Women, one-half of our population and one-half of the potential candidates among youngsters to become engineers and scientists, are today making only a small—13 percent—contribution to the totals. Much more can and should be done to utilize this resource. We could add half again as many engineers and scientists to the Nation's total human resources by the year 2000 if we were to set up appropriate programs to encourage, aid, and educate that large fraction of young women who possess the innate ability to enter these professions. We must also work to change our national pattern so as to bridge the cultural and economic gaps and bring minorities and the handicapped into the engineering and the science world. As to women, minorities and the handicapped, the National Science Foundation has begun excellent programs, but again they are much too modest in funding, ambition, and space—and pace. Looking at this wall here, it is difficult to say "pace."

We do not lack for ideas, and we do not lack the national talent to develop more ideas—practical ones, achievable ones, ideas that would be effective in a decade or two in reversing America's technology leadership slip and future insufficiency of supply of scientists and engineers. But this is a time of severe budget deficits and a need to control Federal Government spending. Where are the funds to come from to attack this shortcoming that, if not countered, will prove so penalizing to the Nation in the years to come?

I submit to the committee that the answer is to be found in reallocating existing funds within present budget levels. Difficult as it is to accomplish, and difficult, also, for some even to contemplate, we must take funds from our backing of immediate problem-solving and invest it in the future. We are imbalanced in the tradeoff of expenditures for meeting short- and long-term objectives. Consider, for example, the issue of national security. Whether it be handling potential hostilities with the Soviet Union or satisfying a broad array of detailed requirements to cover possible troublespots and threats all over the world, the security problem is surely not one of short duration. Realistically, we will need more technological dimensions to augment military strength for as many years ahead as we can see. We are now spending about $1 billion a day on national defense efforts. Suppose that, to guarantee our security for the second decade from now, we were to employ an additional $1 billion annually, taking it away from the defense budgets planned for the immediate decade ahead. The result would be that whatever stance we now expect to present to the Soviet Union and the rest of the world, we would be 10 days late in doing so by the end of the decade. In accepting that minor penalty, our long-term security would be protected.

Already the programs of the Department of Defense are suffering because in the past we failed to prepare for today's high technology effort. Neither the DOD internally nor the technological industry has an ample supply of outstanding, well-educated engineers and scientists ideally suited to planning and executing the tremendously sophisticated R&D, design, and production that characterizes modern weapons systems. In a bind for talent, industry has been pulling away top professors, and the brightest students before they finish their Ph.D. work, making the challenge of achieving quality output from our engineering schools even greater. We should not be surprised when we experience steadily increasing overruns in cost and time and disappointments in performance of high technology equipment deliveries by the industry.

The growing appreciation that we have a serious national problem has caused the National Science Foundation to be urged to do what its charter has always called for it to do. In response, the Foundation is now dealing with the several critical issues, including: Replacing the out-of-date, shrinking and decaying instrumentation, facilities and equipment in American colleges and universities; augmenting science, engineering, and mathematics education, from kindergarten through graduate study; bringing women, minorities, and handicapped into the mainstream of our technological society. These new programs need to be carried out and broadened while steadily growing international competition in pure science impels increased sponsorship of basic scientific research in the universities. The ratio of nondefense R&D to GNP for the United States—1.9 percent—in 1983 was well below that of Japan—2.6 percent—and West Germany—2.5 percent. The National Science Foundation, with its fixed budgets, cannot starve one essential program to feed another without consequent undernourishment everywhere.

The Chairman of the National Science Board and its members and the Director for the National Science Foundation and his staff are all now more than merely interested. They are determined, zealous, and ready for action. The seeds that they have planted in the last year or two are now little buds needing water, fertilizer, cultivation, and growth.

But the budget isn't there.

That ends my testimony. I would be happy to hear any questions.

[The prepared statement of Dr. Ramo follows:]

TESTIMONY BY DR. SIMON RAMO

Before the Committee on Science and Technology
Task Force on Government Science Policy

Mr. Chairman and Members of the Task Force, the following testimony expresses my strong conviction that as a nation we have been severely underinvesting in the long-term strength of our science and engineering. That shortcoming has many dimensions. I shall comment on several of them, starting with one concerning which the Chairman of the Committee on Science and Technology, Representative Fuqua, recently has been quoted as follows:

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But the budget isn't there.

Mr. **Fuqua**. Thank you very much, Dr. Ramo, and now we will hear from Dr. Nacht.

[A biographical sketch of Dr. Nacht follows:]

Dr. Michael Nacht

Michael Nacht is Associate Professor in the School of Public Affairs of the University of Maryland where he teaches and conducts research on national security policy, public management, and problems of international education.

Mr. Nacht was born in New York, New York September 1, 1942. He received a B.S. in Aeronautics and Astronautics (1963) and an M.S. in Operations Research (1969) from New York University, an M.S. in Statistics (1966) from Case Western Reserve University, and a Ph.D. in Political Science (1973) from Columbia University. He has had professional experience in government, the private sector, and academia. From 1963 through 1966 he was an aerospace engineer at the NASA Lewis Research Center in Cleveland Ohio. From 1966 through 1970 he was a senior scientist at Dunlap and Associates, Inc., a management and systems consulting firm in Darien, Connecticut. From 1973 through 1984 he held a variety of faculty and administrative posts at Harvard University including Associate Professor of Public Policy and Associate Director of the Center for Science and International Affairs at Harvard's Kennedy School of Government. He also served as Acting Director of Harvard's Program on U.S.-Japan Relations. He joined the faculty of the University of Maryland in 1984.

Mr. Nacht has co-authored with Professor Craufurd Goodwin of Duke University two monographs on international education. *Absence of Decision: Foreign Students in American Colleges and Universities* (Institute of International Education, 1983) and *Fondness and Frustration: The Impact of American Higher Education on Foreign Students With Special Reference to the Case of Brazil* (Institute of International Education, 1984) and is presently completing a third study that examines decline of competencies in Mexico, Indonesia, and Turkey. He is the author of more than thirty professional articles and book chapters concerned with national security policy. His book *The Age of Vulnerability: Threats to the Nuclear Stalemate* was published in April 1985 by The Brookings Institution. He has also been a consultant to a number of government agencies, private foundations, and corporations.

STATEMENT OF DR. MICHAEL NACHT, ASSOCIATE PROFESSOR, SCHOOL OF PUBLIC AFFAIRS, UNIVERSITY OF MARYLAND, COLLEGE PARK, MD

Dr. **Nacht**. Thank you, Mr. Chairman.

As I interpreted my task, there were two parts. The first was essentially to summarize the main points of what others had said and to essentially address the question, where should the task force go from here? and, second, to offer some particular comments on the question of the connection between foreign students in the United States and this question of science and engineering manpower.

I am just going to very quickly review six points which I think essentially highlight what most of the testimony has converged upon, and what might essentially be a first draft of an agenda of what happens next after this task force has been completed. I won't even read the testimony. Let me just quickly go through them.

The first—and, obviously, it follows directly from what Dr. Ramo has just said—is the funding question. There are really two essential points that seem to come out of expert testimony on this.

The first is that there has been a decline in funding in many areas related to science and engineering manpower, particularly federally-funded fellowships and traineeships, which have declined every year from 1976 through 1983.

Second, since Sputnik and the American reaction to Sputnik, we have a kind of roller-coaster behavior of federally-funded programs. We have up periods and then down periods. Obviously, this is very difficult for institutions or individuals to plan effectively in terms of how they can use these funds, because they don't know from year to year what funds are generally going to be available. So, in an era of extraordinarily difficult economic times, with huge budget deficits and pressures upon yourself and others to cut back on the Federal budget, what can we really expect to do in this area?

One thought, which is actually not in my testimony, but let me just raise it for consideration by the task force, probably the biggest game in town now in the science and technology area is the President's Strategic Defense Initiative. After all, the President is requesting $26 billion over a 5-year period. The Congress is going to be grappling with this request for several years. Perhaps the SDI could in fact be the Sputnik of the 1980's and could be divided, siphoned, massaged, and manipulated so that at least some of those funds could be not merely for very exotic research programs at Lawrence Livermore Lab or Los Alamos on the Strategic Defense Initiative, but also to fund programs in science and mathematics and engineering education which really undergird a lot of this highly advanced work.

The second point that comes through over and over again in the discussions and a lot of other literature on this subject is that the very basic roles of the major institutions are becoming blurred. Do you know what? At first blush, you could say, "Well, the basic research is done in the universities; the industry community basically does applied research and Government does a little of each and spends a lot of time monitoring contracts."Now, if you probe each of the three sectors, what you find is that there is an awful lot of applied research going on in universities; there is quite a lot of basic research going on in industry. Increasingly, the most effective kinds of programs involve a marriage of Government, industry, and the academic community. I think it would be quite appropriate for the task force to consider ways in which this kind of synergism, this marriage across sectors, could be promoted. I will have a little bit more to say about that at the end of my testimony.

A related point here is that of all the projections concerning scientific and engineering manpower, probably the most crucial gap as we head further into the future is the number of Americans who are preparing themselves to teach engineering in America's colleges and universities. There is a huge gap between what is needed and what is available. Some estimates range as high as 6,700 vacant positions in engineering faculty, most of which are taken up by non-Americans. The reason for this is almost purely an economic fact of life. Recipients of a baccalaureate degree in engineering receive a starting salary in most cases which exceeds those of the assistant professors who have been teaching them, and with increasing time, their salary prospects are far more attractive than those of their professors. Also, corporations provide very generous tuition reimbursement programs and other kinds of incentives to go to school on a part-time basis. So, in practical economic terms, very few people—and I was one of them—upon receipt of a bachelor's degree in engineering, really have a great economic incentive to continue on in graduate school, because the economic pull is so great in industry. The net effect of this is that, essentially, we have had a lost generation of American engineering faculty. We have large numbers of non-Americans teaching engineering, many of them with limited knowledge of English. We have got huge social and intellectual problems in terms of foreigners teaching Americans and having difficulty conveying the concepts because of their limited English language capability. It is an enormously difficult problem.

Another point I would like to make is that, as Dr. Ramo said, on the women front and on the minority front, you essentially have a huge untapped resource here. You have very large numbers of potential engineers and scientists who, for a variety of reasons—social, economic, and so forth—have just not been tapped to move into these fields. There is no doubt that the positions are available. There is no doubt that the incipient talent is there. The problem is in connecting the talent up to the positions, and that involves, I think, very aggressive work on the part of Federal agencies to encourage youngsters—women and minorities—at young ages to think more vigorously about pursuing work in science and engineering to attract the best talent that we can. It is a huge untapped resource.

On the question of scientific faculty, faculty in the sciences in contrast to faculty in engineering, we have a rather different situation which comes through again in a lot of the literature, which is sometimes classified as the middle-age bulge, something I am personally suffering from at the moment. Basically, the theme of the work that has been done on faculty who teach physics, chemistry, et cetera—not in engineering but in the physical sciences—is that you have very large numbers of highly tenured faculty. Most of them are over the age of 40, which means that for another 10 or 15 years, we are in pretty good shape on that front. We don't have actually that many openings for younger faculty to enter physics and chemistry and mathematics departments. But, in the mid-1990's, we are going to have a large number of openings because these people will be retiring. Since there aren't the incentives being created for people to move into this field, it is not clear, if we continue current practices, that the people will be available to take on these faculty positions a decade hence.

Let me skip on, then, to some points concerning the foreign student connection, which has not been highlighted very much in these hearings. I have been engaged for 3 years in a number of studies on the composition of the foreign student body in the United States, who they are, why they come here, what their role is, how they affect the institutions in the United States, what happens when they go back home, and so forth. Let me make just a couple of general points.

There is no doubt that the United States remains the principal attraction for a non-American if you want to study science and engineering. It has the image as the frontier, as the best place to study with the best people, the most open society, the most open kinds of academic institutions where you can pursue academic inquiry without fear of being constrained in any particular way.

There is no doubt that the work experience that sometimes students get while they are studying here is also very valuable to the non-American. There is also no doubt that many of the non-Americans, upon return home, are rewarded for having a prestigious American degree in their pocket, for having made contacts with the Americans, and so forth. And there is also evidence to show that a good number—although the precise number is hard to identify—a good number of non-Americans are studying in this country because they also plan to live in this country afterward.

What is the impact of all of this? Well, I don't think it is just a kind of dry academic exercise. There are quite considerable economic and national security questions here, besides sociological and intellectual questions. For example, we are embracing large numbers of people primarily from East Asia, who are among our fiercest economic competitors. Should we do this in a completely open-ended fashion? Should we knowingly—or perhaps just unconsciously—be training our economic competitors in advanced management practices and how to engage in production engineering most efficiently, and how to do economic analysis with the best of the Americans?

What about in the national security area? The visit just this week of this high-level Chinese delegation: we are going through a fundamental transformation in our relationship with the People's Republic of China. Should there be any constraints at all on the types of Chinese who come to study here, on the subjects that they can study? Should it be a free marketplace, or should we think through, perhaps more than we have, whether certain areas ought to be off limits or not.

I don't have ready answers to these questions. All I am saying is that if you go around the country and speak to quite senior educators in American colleges and universities and people in industry and people in Government, I don't think very many people at all have thought through the implications of these very fundamental changes in our relationship with the People's Republic of China and some other countries, particularly in East Asia.

Another point related to this question of the American students not staying on in graduate school in engineering but going into industry is that you have very high capital-intensive investments in engineering departments. You have huge facilities. I was an aeronautical engineer at one point, and I can remember working with very sophisticated wind tunnels. Well, if suddenly the American students are not studying at the graduate level, what do you do with these wind tunnels? What you do is you make sure you admit enough non-American students so you can keep your departments open. So there is a phenomenon which my colleague and I have called "foreign students as filler." Foreign students are being actively recruited by engineering departments because there is no alternative for these departments. I have personally visited some major State universities in this country where almost none of the graduate students were Americans. So this is really a quite extraordinary problem.

Finally, let me end with three basic points to look toward with respect to this whole set of issues. The first I call the East Asian connection. If you look at all the data concerning who is coming to this country, where the real trends are, there is no doubt that the dominant impact on engineering and science education coming from abroad is coming from a small set of countries in East Asia—Japan, Korea, Taiwan, the People's Republic of China, Malaysia, Singapore, and Hong Kong. They are extraordinarily talented; they are diligent; they are hard working; they are the best in their classes. Many of them go back home and do a great deal for their own societies. We really have not thought through very much what this is doing for our own foreign policies, for our own bilateral and multilateral economic relationships with them, nor for our own science and engineering education. I think a lot more could be done to understand more effectively what this East Asian connection is doing to American science and engineering education and American science and engineering manpower.

You know, a few years ago, the United States shifted, for the first time in its 200-year history, away from Europe and toward Asia as our dominant trading partner. We trade more today with the Asian countries than we do with the European countries. All the trend lines suggest that the gap will widen. There are 9,000 Taiwanese studying in this country today, and there are 6,000 from all the West European countries. Three-quarters of these Taiwanese students are studying science and engineering at the graduate level. We have a huge program that is developing here, a huge market involving engineering and science education for East Asians, and we don't really even understand what it is that we are doing or what the effects are of this extraordinary shift.

The second point which I think the Science Policy Task Force ought to consider further is what I had discussed earlier concerning this Government-academic-industry synergism. You have at least four major centers in this country now that are really at the forefront of American science and technology—the Route 128 strip around Boston, the Research Triangle in North Carolina, the Austin, TX, area around the University of Texas, and the Silicon Valley area south of Palo Alto. If you probe how they got to where they are, what you find is that it is not a master plan, but it is basically an openness to the synergism of strong academic institutions, entrepreneurial talent on the part of many people in the private sector, and very sensitive Government agencies wanting to promote this kind of interaction. I think the Science Policy Task Force perhaps could do more fruitful work on how to promote this synergism in other parts of the United States.

The third and last point I would just make is not a very exciting point, but I think, increasingly, it is an important one, and that is, outside of the major centers of research, the technological pace is so rapid that it is almost impossible, unless you are as talented as a Si Ramo, to keep up with what is going on. The decline in your competency just is very dramatic. Every day there are new developments, and if you are not subscribing to all the journals, if you don't have top people to interact with and learn from, if you are not constantly going to seminars or workshops or short courses, you fall behind almost instantaneously. We can call this, politely, decline of competency. Some people have called it professional and intellectual decay. Whatever you want to call it, it is a real problem, and in most of our engineering and science programs outside the major research centers, this is very pronounced. I think funds need to be channeled. It is not a sexy, exciting, prestigious area, but it is a very important one. We need to be able to continue to upgrade and renew the talent that we have already got, and we are currently not putting the funds available to permit this to happen.

Thank you.

[The prepared statement of Dr. Nacht follows:]

STATEMENT OF MICHAEL NACHT, SCHOOL OF PUBLIC AFFAIRS, UNIVERSITY OF MARYLAND

It is a privilege to appear before the Science Policy Task Force of the Committee on Science and Technology to address the subject: "Scientists and Engineers: Supply and Demand."

This Task Force has taken hundreds of pages of testimony in six days of hearings and has heard from witnesses drawn from the academic community, various government agencies, and the private sector. Chairman Fuqua's letter of invitation stated that I could be of most help to the Task Force during this final session by 1) identifying "the essential questions we must address to assure an adequate supply of qualified scientists and engineers in the future; and 2) help the task force "understand the general social forces which generate situations such as the apparent upsurge of foreign-national students."

I have had an opportunity to review the statements of the witnesses who appeared before the Task Force in the first three days of hearings. I have consulted a variety of publications on scientific manpower. And, with particular reference to the second task cited above, I have co-authored two studies on the impact of foreign-nationals on American colleges and universities and am currently engaged in a third (these are cited in my biographical sketch attached to my statement).

Drawing upon these sources I will first identify the main points that are most relevant to the concerns of the Task Force:

1. There is general acceptance of the view that the Federal Government plays a vital role in funding teaching and research programs in engineering and the sciences. The principal concerns are twofold: first, there has been a secular decline in federally-funded fellowships and traineeships extending from 1976 through 1983; second, federal funding has taken large and sudden swings since the U.S. reaction to Sputnik in 1957, causing great difficulty for institutions and individuals engaged in long-range planning for training or research programs that are dependent on government support. We know that every President from Nixon through Reagan has run "against" the federal government and has publicly advocated trimming support for most non-defense programs. In an era of huge budget deficits how can federal funds for science and engineering manpower be realistically expected to grow? And what kind of budgetary devices, including multi-year funding packages, would relieve the uncertainty associated with federal support?
2. Most specialists expect there to be adequate supplies of engineering and scientific manpower for the next five-to-ten years. Important

exceptions are engineering faculty, computer-related professions, and certain scientific specializations. The problem of shortage is especially acute with respect to American citizens who hold the doctorate in engineering and take faculty positions at major research-oriented universities. Unquestionably, this shortage has been brought about by an economic marketplace in which recipients of the baccalaureate degree in most engineering disciplines can expect to receive starting salaries equal to or in excess of those of assistant professors. Moreover, corporate employers, who recruit the majority of engineering graduates, often offer attractive tuition payment programs as an incentive for their employees to continue graduate work on a part-time basis. Consequently, from an economic perspective, there are enormous disincentives to pursue the engineering doctorate and to then enter academic life. It would appear that somewhat more generous fellowship support than is presently available will have little effect on this incentive structure. Rather cooperative programs between the academic community and the private sector are required. **How could federal funds be channeled to promote university-business cooperation that would alleviate the severe shortage**

(estimated as high as 6700 positions) of American engineering faculty? More generally, how can university-industry relationships be encouraged that would guarantee academic freedom and yet provide resources useful to the private sector?

3. It is apparently becoming increasingly difficult not only for major universities to recruit top engineering and, in some cases, scientific talent to their faculties; it is also a challenge for government research laboratories to hire and retain such individuals. Even the National Aeronautics and Space Administration (NASA), which historically has had great success in their "acceptance rate" of new recruits--surely in part because of the organization's prestige and in part because of the calibre of the personnel and equipment associated with NASA--is experiencing noteworthy difficulties. Again, the issue is one of economic incentives favoring the private sector. A consequence of this condition is that scientific and engineering leadership is being increasingly exercised in organizations that are more dominated by private than by overall public policy motivations. **How, then, can federal funds be utilized to strengthen the salary and**

fringe benefit package of government-employed scientists and engineers in order to be more competitive in the manpower marketplace?

4. There is continued underrepresentation of women and minorities in the sciences and the engineering professions. There appear to be fine opportunities for well-trained women and minorities in all sectors of the manpower pool: academic, government, and industry. There is simply an acute shortage of such talent available. What specialized programs could be established that would attract more women and minorities to scientific and engineering careers?

5. Contrary to the situation in engineering faculties, most academic departments in the physical and biological sciences are presently "well stocked" with large numbers of tenured faculty over the age of 40. This is sometimes referred to as the "middle age bulge." It is expected that by the early 1990s many of these faculty will be retiring, producing large numbers of faculty openings. What programs initiated in the mid-1980s will ensure that there is a plentiful supply of scientific talent ready and able to devote themselves to academic careers seven-to-ten years hence?

6. There are also questions of insufficient data and data analysis efforts which raise doubts about the validity of each of these general observations. Historically, many of the professional associations and scientific societies have been quite good at "looking after their own." Would it be useful, therefore, for federal funds to be provided to an overarching body, such as the National Academy of Sciences and/or the National Academy of Engineering, to permit more intensive data collection and analysis, drawing in part on data already in the hands of the various professional societies? And how should government funds mesh with support from private foundations to strengthen the analysis of these scientific manpower issues?

I believe that these questions address the central issues that should serve as part of the "follow-on agenda" for the Task Force. The other part of this agenda, which has not been dealt with fully in the hearings up to this point, concerns the "foreign student" connection (I will use the term "foreign student" as a synonym for "international student" or "foreign-national student.") To be as succinct as possible, I will first summarize the main points of my research on these issues and then suggest what follow-up steps are in order.

Principal Findings from Research on Foreign Students

1. There are in excess of 350,000 foreign students studying in American colleges and universities with perhaps 25% of these studying engineering or science at the graduate level in duly authorized degree programs. Most institutions of higher learning do not have an overall strategy for how many and which type of students to admit. Social, economic, and political problems appear to arise if the total number of foreign students in any one program or category exceeds 20% of the total number of students enrolled. Most admissions decisions at the graduate level in science and engineering are made by the individual departments. In some cases student recruitment is closely tied to the entrepreneurial and international interests of particular senior faculty. Overall, then, there is an ad hoc quality to the foreign student decision-making process.

2. Foreign students come to the United States to study engineering and science because it is the recognized world leader in many of these fields; because they are attracted by the dynamism and openness of American society; because they appreciate the freedom of scholarly inquiry available in U.S. colleges and universities; because they feel they will be handsomely rewarded in terms of their own careers when they return home with a prestigious American degree; and, in some cases, because they are

planning to relocate permanently to the United States (exact numbers of graduate students who ultimately take up permanent residence in the United States is difficult to measure.)

3. Besides intellectual and social questions, issues of economic protectionism and national security are intimately connected to the "foreign student question." Should the United States train individuals in scientific and engineering methods that can ultimately be applied in the design of weapon systems by their home governments? Should American institutions impart skills of managment, economic, and production analysis which would be useful in assisting foreign industries that are current or potential strong economic competitors to American industry? These are difficult issues--analytically and emotionally--and are not susceptible to easy analysis. Should there be a differentiated policy, permitting some students to study certain sujects but not others--for example, is it practical or desirable to permit Japanese to study solid state physics but to prohibit Chinese from the People's Republic of China from such academic work?

4. Because of the problem of recruiting American engineering graduate students, many departments are filled with foreign students and faculty members. My co-researcher and I encountered engineering departments at major state universities in which there were more than fifty graduate

students enrolled none of whom were American nationals! Problems of understanding foreign students serving as teaching assistants are particularly acute. Because engineering departments are so heavily capital intensive, foreign students are used as "filler"--departments would literally have to shut down without them.

5. Foreign students often do not receive training in the United States that is most appropriate to the needs they will face when they return home. Oftentimes, upon return they begin to lose their skills because they no longer have the equipment, peer interaction, and access to the professional literature that is essential for maintaining state-of-the-art knowledge.

6. There are many "side payments" in interacting with foreign students that are not often appreciated in the American technical community: joint research projects; opportunities for student and faculty consulting abroad; and the encouragement of foreign investment in the United States, to name a few.

Given these findings, let me point to three issues which I believe deserve further investigation:

1. The East Asian Connection - increasingly science and engineering programs at the graduate level are being populated by talented and energetic students from Japan, Korea, Taiwan, the People's Republic of

China, Malaysia, Singapore, and Hong Kong. These states are presently all economic partners and competitors of the United States; some are tied to the United States in security agreements; others have been or could again be adversaries of this country. The numbers are now quite large. On my own campus at the University of Maryland, for example, roughly half the foreign students are from East or South Asia (more than 800) with the most rapid increases stemming from the People's Republic of China. Nationwide there are 150% more students from Taiwan than from all the countries of Western Europe combined, and 75% of these are studying science and/or engineering. To my knowledge no study has been conducted on the East Asian connection in terms of its effect on American institutions, U.S. science and engineering, and the academic and economic life of these countries. As the United States swings increasingly toward Asia as our dominant trading partner, these issues will take on increasing significance.

2. Government-Academic-Industry Synergism - In the complicated world of contemporary science and engineering, all three sectors of our economy and indeed of other economies need to work more closely together. In the United States the major technical success stories--Route 128 near Boston, the Research Triangle area in North Carolina, the community around

Austin, Texas, and the Silicon Valley area--are all stories of synergistic relationships among strong universities, entrepreneurial talent, and opportunistic (in the positive sense) governmental institutions. These partnerships need to be encouraged nationwide, in part through federal support.

3. Decline of Competencies - at other than the major research centers, the pace of scientific and technological advance is so rapid that only the most talented can keep pace. It is not good enough to have a doctorate in one's pocket. Continuous upgrading and "renewal" is required for most professionals to remain technically productive. This is most appreciated in the private sector, less so in government, and least in academia. Short courses, intensive workshops, grants for periodical acquisition and the like are vital for the technical community to retard competency decline. This problem is acute in various parts of the United States and is even more pronounced in developing countries. Funds for these activities should not be considered as secondary or tertiary priorities.

I hope these remarks provide a useful basis for the panel discussion that will now follow.

Mr. **Fuqua**. Thank you very much, Dr. Nacht.

Dr. Kuh.

STATEMENT OF DR. CHARLOTTE V. KUH, DISTRICT MANAGER, FINANCIAL PLANNING AND BUSINESS RESEARCH, AT&T TECHNOLOGIES, INC., BASKING RIDGE, NJ

Dr. **Kuh**. Thank you, Mr. Chairman.

I am pleased to have the opportunity to speak to you about the potential role of continuing education in maintaining a qualified pool of scientists and engineers.

Although my present work at AT&T does not directly involve me in science and engineering personnel issues, before coming to AT&T, I did research on economic and demographic models of academic demand for Ph.D.'s and for science and engineering personnel in particular. AT&T has permitted me to keep up my involvement in these questions by releasing my time so that I can serve on a number of advisory committees of organizations interested in this area. In particular, these are: the Advisory Committee of the Science Resource Studies and Policy Analysis Section at NSF; the Advisory Committee of the Office of Science and Engineering Personnel at the National Research Council; and the Committee on National Needs for Biomedical and Behavioral Research Personnel of the Institute of Medicine. However, the views that I shall express here are my own and not those of AT&T or any of these other organizations.

The invitation to testify before this committee gave me an opportunity to look ahead to the likely science and engineering personnel situation over the next two decades. Let me paint the picture that would be drawn by a demographically-driven paintbrush and discuss possible adjustments that would alter this picture.

The next 10 years are going to see a shrinking of the 18- to 24-year-old population cohort by 20 percent. Popularly known as the baby bust, this shrinking is going to have a profound effect on academia and its graduates. There are likely to be fewer students and an aging faculty.

In the last decade, our colleges and universities graduated almost 300,000 science and engineering baccalaureates and first professional degrees per year. During the next decade, if the percentage of undergraduates choosing science and engineering majors does not change radically, the number of S&E degrees is going to drop by about 13 percent to 260,000 per year. The magnitude of this drop is more impressive when you contrast it to the fact that we have seen 16 percent growth in science and engineering first degrees since 1970. After 1995, these numbers will rise slightly and then stabilize if current demographic trends stay what they are.

First degree recipients are not ready to be research personnel, but they are the pool from which research personnel are drawn. The turn-around in the growth of this pool means that Government, industry, and even academia, which have been able to fill their needs for new scientists and engineers with new graduates, will observe fewer applicants and will engage in much more vigorous recruiting. There is then likely to follow a period of rapidly rising salaries for new entrants. But, for the system as a whole, all the scientists and engineers desired, given the previous decade's levels of hiring, will not be there. This is a serious change, since, up until now, we have relied on new graduates to embody the latest knowledge in their field.

These shortages are likely to hit the different fields of science and engineering differently. Supply in engineering and computer science, for example, seems to have been very responsive to changing market conditions. Supply in the physical sciences, on the other hand, has been almost constant at around 2 percent of bachelor's degrees for over a decade. Life science graduates have actually been declining during a period of growing demand in at least some areas of biology, and total science and engineering graduates are a remarkably constant share of total first degrees.

How is the system likely to adjust to the new facts of personnel availability? I see three principle modes of adjustment,

First, expansion of supply. There are likely to be attempts, which have been recommended by everyone on this panel as well as yesterday, to get increased participation of previously underutilized groups, principally women and minorities, to bring them into science and engineering careers.

Second, replacement of demand for people with capital that performs similar functions. An example of this type of adjustment is the increasing use of CAD/CAM technology and the increased use of computerized expert systems. We can substitute machines for people in at least some skilled work.

Third, the redirection of the skills of the existing stock of scientists and engineers toward areas where they are in greatest demand. This is where continuing education comes in.

I have tried to find out what we currently know about continuing education and how much goes on, and I found that there is very little information currently available on this issue. There is an immediate need for data and analyses of continuing education undertaken by scientists and engineers. If public policy is to encourage participation in continuing education, there should be a base line that could tell us how much continuing education was going on in the absence of such explicit policy. Current statistical collection, however, is sporadic and, for example, is not differentiated by degree level of participant.

If such data existed, we would certainly want it to distinguish between employer-provided continuing education and employee-financed continuing education. Employer-provided continuing education is likely to be used to match employee skills with new technology or to improve employee morale and productivity. Employee-financed continuing education, on the other hand, is more likely to be used by the individual to change either fields or employers.

In the absence of extensive analyses, however, we do know that even at present a great deal is being spent by employers on continuing education. The American Society for Training and Development estimates that in 1981, over $210 billion was spent on continuing education, most of it on on-the-job training. But that was both in job and in formal settings. If we look to statistics about scientists and engineers, the latest I could find had to do with 1976, but then about 1.3 percent of all scientists and engineers were enrolled in degree credit courses. As much as an additional 8 percent may have been enrolled in non-degree credit activities.

We also know that responsiveness to changing demand conditions does exist in the pool of scientists and engineers. A study of field mobility of doctoral scientists and engineers, conducted by the National Research Council, found the greatest mobility to be among mathematicians and physical scientists. The overwhelming reason for switching fields was "more attractive career options." This study, however, did not tell us whether continuing education was used to accomplish the switch.

Even in the absence of detailed studies of continuing education for scientists and engineers, I think there are some general guides to the direction of public policy in this area.

In general, I think that public policy should be designed to assist market mechanisms to attain national goals. It cannot mandate massive redirections of science and engineering personnel. The market mechanisms that signal shortages to scientists and engineers are rising salaries and good career opportunities. These signals are provided naturally by employers who wish to be successful in the marketplace. Individuals, motivated by their own abilities and these market attractions, are likely to undertake the continuing education necessary to fill shortages that appear. But although shortages will eventually disappear, there may be costly delays or compromises in quality while the adjustment is being made.

In addition to market mechanisms, there are now in existence tax policies to encourage continuing education. The tax law currently provides writeoff to employers and tax deductions to employees who undertake continuing education to improve skills in their present job. Additional direct aid to employers is likely to result simply in the substitution of public funds for private funds. If training and retraining of employees are profitable for employers, they are likely to undertake it out of their own pockets.

These incentives, however, do not operate for scientists and engineers who wish to undertake continuing education to change fields or change fields and employers. Continuing education for these people could be assisted by relaxing some of the eligibility requirements for student aid such as full-time attendance. Expanding tax deductibility of education expenditures to include education for field mobility might also help, although, of course, expanding the deductibility of anything these days is not fashionable.

Educational institutions need to be able to supply equipment that is state-of-the-art for the training of both new and returning scientists and engineers. Achieving this might involve Federal assistance for equipment expenditures to educational institutions, and I understand this committee has been active in that area.

Much science and engineering training and retraining requires a strong foundation in mathematics and in general science. Public policy should do everything possible at the college and precollege level to improve the quality and extent of mathematics education. Applied mathematics exposes the student to conceptual models that are applicable to many branches of science and engineering. If students are taught these foundations and their generality early, the barriers between fields and disciplines will seem less formidable.

Finally, it is difficult to formulate public policy toward continuing education with virtually no facts. Data on continuing education, collected on a continuing basis, using a uniform methodology, should be funded at the Federal level.

In the market for scientists and engineers, as in most other markets, supply in the long run adjusts to meet demand. My view of the Federal role in continuing education in this process is to assist the flexibility of existing scientists and engineers to adjust to market conditions.

This involves, first, better data collection on continuing education, so we know where we are; second, some expansion of eligibility for student aid and for tax deductibility of education expenditures; third, equipment aid to educational institutions; and, fourth, appropriate measures to strengthen the teaching of precollege and college mathematics.

Even without such assistance, supply will adjust to meet demand, somehow. But the adjustment may be slower than desirable or quality may suffer. If we wish to assure that the adjustment results in the movement of high quality, well-trained scientists and engineers to emerging areas that serve national needs, these measures will help.

I thank you, and I am glad to answer questions.

[The prepared statement of Dr. Kuh follows:]

Statement of Dr. Charlotte V. Kuh
District Manager
Financial Planning and Business Research
AT&T

Prepared for the Task Force on Science Policy
House Committee on Science and Technology

July 25, 1985

Mr. Chairman, I am pleased to have the opportunity to speak to you about the potential role of continuing education in maintaining a qualified pool of scientists and engineers.

Although my present work at AT&T does not directly involve me in science and engineering personnel issues, before coming to AT&T I did research on economic and demographic models of academic demand for Ph.D.'s and for science and engineering personnel in particular. AT&T has permitted me to keep up my involvement in these questions by releasing my time so that I can serve on a number of advisory committees of organizations interested in this area. These are:

- the Advisory Committee of the Science Resource Studies and Policy Analysis Sections of the National Science Foundation,

- Advisory Committee of the Office of Science and Engineering Personnel of the National Research Council, and
- The Committee on National Needs for Biomedical and Behavioral Research Personnel of the Institute of Medicine.

The views I shall express here are my own and not those of AT&T or any of the above organizations.

The invitation to testify before this Committee gave me an opportunity to look ahead to the likely science and engineering personnel situation over the next two decades. Let me paint the picture that would be drawn by a demographic paintbrush and discuss possible adjustments that would alter this picture.

The Demographic Picture: 1990-2010

The next ten years are going to see a shrinking of the 18-24 year old population cohort by 20%. Popularly known as the Baby Bust, this shrinking is going to have a profound effect on academia and its graduates. There are likely to be fewer students and an aging faculty.

In the last decade, our colleges and universities graduated almost 300 thousand science and engineering (S&E)

baccalaureates and first professional degrees per year. During the next decade, if the percentage of undergraduates choosing S&E majors does not change radically, the number of S&E degrees is going to drop by about 13% to 260 thousand per year. The magnitude of this 13% drop is more impressive when contrasted to the 16% growth in S&E first degrees that we've seen since 1970. After 1995, these numbers will rise slightly and then stabilize.

First degree recipients are not ready to be research personnel, but they are the pool from which research personnel are drawn. The turn-around in the growth of this pool means that government, industry, and even academia, which have been able to fill their needs for new scientists and engineers with new graduates, will observe fewer applicants and will engage in much more vigorous recruiting. There is then likely to follow a period of rapidly rising salaries for new entrants. But, for the system as a whole, all the scientists and engineers desired, given the previous decade's levels of hiring, won't be there. This is a serious change, since new graduates embody the latest knowledge in their field.

These shortages are likely to hit the different fields of science and engineering differently. The supply of graduates in engineering and computer science, for example, seems to have been very responsive to changing market conditions. The supply of physical science graduates, on the other hand, has been almost constant at around 2% of bachelor's degrees for over a decade. Life science graduates have actually been declining during a period of growing demand and total S&E graduates is a remarkably constant share of total first degrees.

How is the system likely to adjust to the new facts of personnel availability? I see three principle modes of adjustment:

1. Expansion of supply. There are likely to be attempts to get increased participation of previously underutilized groups, principally women and minorities, into S&E careers.

2. Replacement of demand for people with capital that performs similar functions. An example of this type of adjustment is CAD/CAM technology and increased use of computerized expert systems.

3. Redirection of the skills of the existing stock of scientists and engineers toward areas where they are in greatest demand.

This is where continuing education comes in.

What we currently know about continuing education.

There is very little information currently available about how much continuing education for scientists and engineers there is. Thus, an immediate need is for data and analyses of continuing education undertaken by scientists and engineers. If public policy is to encourage participation in continuing education, there should be a baseline which could tell us how much continuing education was going on in the absence of such policy. Current statistical collection, however, is sporadic and, for example, is not differentiated by degree level of the participant.

If such data existed, we would certainly want it to distinguish between _employer-provided continuing education_, which is likely to be used to match employee skills with new technology or to improve employee morale and productivity, and _employee-financed continuing education_, which is more likely to be used by the individual to change either fields or employers.

In the absence of extensive analyses, however, we do know that even at present a great deal is being spent by employers on continuing education. The American Society for Training and Development estimates that in 1981 over 210 billion dollars were spent on continuing education, both on the job and in formal settings. If we look to statistics about scientists and engineers, in 1976, about 1.3% of all scientists and engineers were enrolled in degree credit courses. As much as an additional 8% may have been enrolled in non-degree credit activities.

We also know that responsiveness to changing demand conditions does exist in the pool of scientists and engineers. A study of field mobility of doctoral scientists and engineers, conducted by the National Research Council, found the greatest mobility to be among mathematicians and physical scientists. The overwhelming reason for switching was "more attractive career options." This study, however, does not tell us whether continuing education was used to accomplish the switch.

Even in the absence of detailed studies of continuing education for scientists and engineers, I think there are some general guides to the direction of public policy in this area.

Public Policy to Encourage Continuing Education.

In general, I think that public policy should be designed to assist market mechanisms to attain national goals. It cannot mandate massive redirections of science and engineering personnel. The market mechanisms that signal shortages to scientists and engineers are rising salaries and good career opportunities. These signals are provided naturally by employers who wish to be successful in the marketplace. Individuals, motivated by their own abilities and these market attractions, are likely to undertake the continuing education necessary to fill shortages that appear. But although shortages will eventually disappear, there may costly delays or compromises in quality while the adjustment is being made.

In addition to market mechanisms, there are now in existence tax policies to encourage continuing education. The tax law currently provides write-offs to employers and tax deductions to employees who undertake continuing education to improve skills in their present job. Additional direct aid to employers is likely to result simply in the substitution of public funds for private funds. If training and retraining of employees are profitable for employers, they are likely to undertake it out of their own pockets.

These incentives, however, do not operate for scientists and engineers who wish to undertake continuing education to change fields or employers. Continuing education for these people could be assisted by relaxing some of the eligibility requirements for student aid, such as full-time attendance. Expanding tax deductibility of education expenditures to include education for field mobility might also help.

Educational institutions need to be able to supply equipment that is "state of the art" for the training of new and returning scientists and engineers. Achieving this end might involve Federal assistance for equipment expenditures by educational institutions.

Much science and engineering training and retraining requires a strong foundation in mathematics. Public policy should do everything possible at the college and pre-college level of improve the quality and the extent of mathematics education. Applied mathematics exposes the student to a conceptual models that are applicable to many branches of science and engineering. If students are taught these foundations and their generality early, the barriers between fields and disciplines will seem less formidable.

Finally, it is difficult to formulate public policy toward continuing education with virtually no facts. Data on continuing education, collected on a continuing basis using a uniform methodology, should be funded at the Federal level.

Conclusion.

In the market for scientists and engineers, as in most other markets, supply in the long run adjusts to meet demand. My view of the Federal role in continuing education in this process is to assist the flexibility of existing scientists and engineers to adjust to market conditions. This involves:

- Better data collection on continuing education, so we know where we are;
- Some expansion of eligibility for student aid and for tax deductibility of education expenditures; and
- Equipment aid to educational institutions.
- Appropriate measures to strengthen the teaching of pre-college and college mathematics.

Even without such assistance, supply will adjust to meet demand. But the adjustment may be slower than desirable or quality may suffer. If we wish to assure that the adjustment results in the movement of high quality well-trained scientists and engineers to emerging areas that serve national needs, these measures will help.

PANEL DISCUSSION

Mr. FUQUA. Thank you very much.

Dr. Ramo—and maybe the others might like to comment—what, in your opinion, is the most important issue in Government science policy that is facing this task force in the long term, for the Federal Government and, for that matter, even the States?

Dr. RAMO. I would say the most important issue is short term: it is attacking the long-term problem and doing so immediately. I would say that education of engineers and scientists and the ensuring of a flow from the universities of well-educated talent, I would put at the top of the list, because it is basic to everything else. I would start virtually at kindergarten when I make that statement. I mean, by education, from kindergarten right up to Ph.D.

Mr. FUQUA. Would either one of you like to comment?

Dr. KUH. Sure. I would like to add one thing which is a way of helping that flow, and this has to do with the stability of funding for graduate education. I think the distribution of ability in the pool of graduate students is roughly the same in every cohort. However, there has really been a roller coaster of funding for fellowships and traineeships, and I think if there were a way to make that a more dependable flow, that that would help a lot.

Mr. MINETA. Will the chairman yield?

Mr. FUQUA. Yes.

Mr. MINETA. Are the numbers that you have in terms of the specifics as to, by discipline, do we have any idea what our needs are? You suggested earlier in your testimony, Dr. Kuh, that you cannot mandate numbers. But, on the other hand, do we have any idea as to what those ballpark figures might be? Are we way short in terms of biochemists and do we have too many civil engineers, and are we too short on some specialty within physics, and do we have too many in materials science? Do we have any ballpark figures on this whole issue of need?

Dr. Nacht.

Dr. NACHT. I have the mike, but she has the numbers, I think.

Dr. KUH. I don't have the numbers, and I think that certainly it is apparent, if there is as much funding of the sort of "Star Wars" initiative as has been asked for, that would require people trained in a variety of disciplines who really don't exist right now. There are certainly going to be shortages there, and there is going to be, I think, a fair retooling of present scientists and engineers to work on those kinds of questions.

Maybe Dr. Ramo has some more information.

Dr. RAMO. Well, the National Science Foundation has, I believe, adequate numbers to provide a rationale for much more substantial programs in all of the kinds of things that the three of us have been discussing, and the National Science Foundation is a part of the Government that has a charter that calls for it to be concerned with all of these matters. I think the National Science Foundation is right now struggling with whether it is preposterous for them to ask for a budget that they have no chance of getting when the practical fact of the matter, as they see the environment, is to be able to hold onto the size of the overall budget it has today. If it does that, and tries to bring in some of these other things like the minority/women issue, like the deteriorating equipment, like the undergraduate in science, like education in engineering, all of these things which they have not been doing very much with, then they would presumably have to take it out of research in science, cutting the budgets, which would be disastrous for the graduate schools that are providing the Ph.D.'s in science, in a world that is growing ever more competitive and ever more technological.

See, there are some generalizations that, once accepted and grasped, it seems to me, at least, really transcend the question of specific numbers. It is a little bit like, if a dam is burst and you are flooded out of your home totally, the precise acidity of the water is not of great interest to you.

When it is true that laboratories are disappearing from our high schools, when science and math teachers cannot be hired and half of them are unlicensed teachers, it is clear we are setting up to be behind, to have an inadequacy, whether the field is biochemistry, computer sciences, or X, Y, and Z that will emerge in the next 5 or 10 or 15 years, which will suddenly be viewed as the hottest area. Whether we want to do an SDI Program or a program to be more competitive with Japan in automobiles, whatever the spectrum is, if there is an adequacy in basic education and basic supply, in training, then we are going to be able to provide adequate statistics.

You know, strangely, we may find that in a meeting of this committee 10 years from now, we are looking at a surplus of engineers and scientists in the United States, no jobs for them, for the reason that we have been beaten out by other nations. So our industry is going down. So we can, in effect, find the shortages not as the starting point but as the consequence of the shortages. The problem takes care of ensuring its worsening.

Dr. NACHT. I would just like to make one additional comment which is really at a somewhat different level, which concerns the basic tenor of the debate as conducted by the executive branch. I am looking here particularly at the role of the President's Science Advisor as, in some way, a spokesman for the American science and engineering community. When that office was set up under the Eisenhower administration, and you had people with the forcefulness and stature of Killian and Kistiakowsky organizing that office, succeeded in the Kennedy years by Jerry Wiesner, you had a tremendous amount of political as well as scientific clout that really made a difference. It affected congressional attitudes; it affected the attitudes of people in science and engineering institutions; and there was a tremendous amount of momentum that developed for science and engineering education.

Starting in the Johnson age, Don Hornig, and getting all wrapped up in Vietnam and so forth, there began, I think, to be a decline in the prestige and the clout of that office. When as talented a fellow as Lee Dubridge, president of Caltech and, I am sure, a close friend of Si Ramo's, became President Nixon's science advisor, he ultimately, I believe, quit out of disgust that he couldn't get anything accomplished, and shortly thereafter, President Nixon decided that the whole thing was sort of a waste of time; he didn't need a science advisor.

President Carter sought to revive this somewhat and appointed, I think, in Frank Press quite an energetic individual, but I don't think, really, he had the prestige or the access to President Carter or the general influence that had been true in the sixties.

Now we have Mr. Keyworth, clearly a competent physicist, Duke-trained, a Los Alamos Weapons Lab Division Director, but he, frankly, doesn't have the stature in the scientific community of some of his predecessors, and he is not pushing very much, as far as I can tell, in these fields.

So, at a very different level, you just don't have any voices from the top of the Executive Branch saying this is a problem; and, in fact, if anything, you have members of the Executive Branch saying that Government should get out; it is up to the private sector; the market will take care of it, and all of this. I think, with that kind of ideology and that kind of absence of initiative, it makes the question only more difficult to resolve.

Mr. MINETA [as acting chairman]. A little earlier, you were talking, Dr. Ramo, about the portion dealing with, I guess, the changing nature of what happens in the private sector and the fact that one time you may have a shortage; another time you have a surplus. Is there a way to sort of get away from those valleys and the peaks in terms of demand and supply of these various disciplines in the scientific and engineering fields?

Dr. RAMO. I cannot imagine that, in the area of employment of scientists and engineers, you can expect to have, in a nation that is part Government-sponsored and Government-regulated and part free enterprise, that you are going to get away from having peaks and valleys, for a large number of reasons that affect them.

There is the general world economy. There is the coming and going of intensity with regard to the defense programs and how they are viewed. Sometimes we feel reasonably secure; sometimes we feel we have gotten behind. Meanwhile, there is the rest of the world that is engaged in activities. As I indicated, we have now only one in four of the industry engineers who are well supported. So three-fourths, one would assume, of all of the major changes, breakthroughs that will happen, and that are upsetting to stability of employment, will originate outside and beyond our control. But being able to adjust to such instabilities in the overall economic picture with the appropriate contributions that science and technology can make to the process, to the health, happiness, economic stability and growth, and security of the Nation requires a base, and we have already allowed ourselves to put ourselves in the position where that base is deteriorating, and rapidly.

So I come back to the idea that, simplistic as it may sound, priorities, first things first, are to start giving more attention to the supply of engineers and scientists from the universities, and that goes back to looking at what we are doing about boys and girls when they are still boys and girls in the primary and secondary grades.

The National Science Foundation has programs laid out, but they more or less have to keep them as a minor appendix to what their present programs are. It is not all that difficult to develop a program which is readily defensible and doesn't have to be perfect, as it never will be.

We are so far from perfect now that a couple of orders of magnitude steps in the right direction are relatively easy to take. But it means that the very difficult idea has to be implemented of taking from the attack on near term problems and moving them over to longer term considerations.

We are acting, as a Nation, as a company acts that is about to go bankrupt. A company that is producing a technological product that is being put out of date by its competitors and sees no way in which it can maintain its revenue is not too interested in setting up a program of research and development to be sure it has the next products so it can compete against the competitors who are going to remain in business. They are not in that situation.

As I pointed out, even in national security, there are some who believe that we are about to be knocked out tomorrow by the Soviet Union in an all-out nuclear attack. If that happens, then all of our discussion perhaps is academic. But if we expect that we are going to have a situation in national security that goes on for decades, and certainly for many years, before its basic nature can change, then we have to provide the wherewithal to carry out our part of the program, and we are not doing that, and we have not done it for a long enough time that, today, we are not up to the competence required to carry out the program that we've got in national security.

Mr. **Mineta**. Mr. Packard. Dr. Packard.

Mr. **Packard**. I haven't been called that for a while.

It appears to me that fundamental to this debate is, should America concentrate its efforts on keeping a premier scientific educational program—which I think all of you have either stated or intimated, that we still are the premier of the world, and thus attract the brightest minds of this country as well as many of the brightest minds of the world to our educational system, recognizing that many of them remain here and contribute here; but if not here, they go back and contribute to the rest of the free world.

Is that the best place to concentrate our funds and our efforts, or is it best to emphasize a program designed to develop within our own people greater interest in pursuing science and technology,and setting up special programs that would enhance and entice them to get into the scientific academia? Where is the best place to put our dollars?

Dr. **Ramo**. Let me attempt a short answer and then pass the microphone to my associates here.

I am sure that there are tangible and intangible benefits that come to the United States, as well as to the world society at large, by having competent graduate students come here and get higher degrees in engineering and science from all over the world. But when you see a figure like 50 percent of the engineering Ph.D.'s this spring were foreigners, when you see that the number of patents granted to Americans has gone down substantially over the last decade, and the number of patents granted to foreigners—foreign-originated R&D created those ideas that are being patented in the United States—rising rapidly and becoming first a major part and then, in a very short time, greater in number than American-originated ones, you know that we have got a terrible imbalance.

You can be forgiven for arguing that you don't have to do too much analysis to know that something is not right about that, and you have only to look back at what is happening in our high schools. Something I didn't say before: about half of our engineering schools are finding they need to teach remedial math to the engineers that they have accepted as incoming freshmen, because they are qualified to be, except that they don't have the math to start calculus, which they should have had in high school. And when you see what other countries—Western Europe, Japan, and even the Soviet Union—are doing with regard to the math education, then you know that we are getting badly behind. It is not going to be totally compensated for by those tangible and intangible values of having foreign students obtaining their degrees here.

Dr. **Nacht**. I personally don't believe that the two options you have laid out, Mr. Packard, are mutually exclusive. I mean, I think one can do both. I do think that, obviously, over time, if much larger numbers of Americans wanted to study engineering at the graduate level, then they would clearly be accepted and welcome, and it would squeeze out some of the non-Americans who had applied, and frankly, American institutions of higher education would welcome the squeezing out of some non-Americans.

In some of my own work, I have spoken to people at 30 major universities around the country, and hardly anyone that was interviewed—and there were over 200 people interviewed—really said, "Gee, we love the situation where 80 percent of our graduate students are non-Americans. It is just that we have no choice."

I think a certain number—and the number that keeps cropping up over and over again is up to 20 percent—is viewed as a healthy mix. It is an internationalization of the program, different perspectives and so forth. We call it the humanist presumption in some of our own writing. It sounds good to be surrounded by people from other countries, and it probably is. But when you get to numbers much greater than that, then I think you really have a problem, and that is the problem facing most engineering graduate programs.

Mr. **Packard**. Does, in your judgment, a strong academic program tend to encourage our youth to get involved in science and high technology areas and careers, or do we find that programs like SDI and our space program, our communications programs, where there is high visibility and a great deal of excitement, do those tend to attract people into those fields?

Again, maybe there is a balance between the two; I don't know.

Dr. **Ramo**. It certainly is not an either/or. Certainly there are forces at play, when we have a shortage of scientists and engineers and we have burgeoning complex, challenging programs that are being funded, salaries will rise; professors will be pulled away from universities; companies will pull away people from each other, raising the salary each time. That will suggest to parents, uncles, nephews, and to reasonably alert youngsters that that is a terrific career, they ought to go in for it. But if you don't provide the basis for their being able to enter those fields, then what will happen will be, ultimately, we will find the industry competing with each other, engaged in doing their own training, hiring people that have too little education—and, of course, that is another good way to describe inferiority for the Nation, if we come to that.

Mr. **Packard**. Dr. Kuh, one question. You spoke on population trends. Have populations trends historically had a significant effect upon the quality or the supply and demand of scientists?

Dr. **Kuh**. That is a hard question because it is really very difficult to have good measures of quality. It is a very hard thing to get a quantitative handle on. But in the work that I alluded to earlier, I have done some work on the probabilities of getting tenure in universities, depending on when people were available to be tenured.

In the sixties, there was a big bulge in university hiring to meet the increased enrollment demand, and the result was that there were much shorter times to tenure for faculty. Now, if you assume that ability is distributed equally among each cohort, that shorter time to tenure would certainly suggest, since ability had not changed, that there was some negative quality adjustment going on, but it was a natural market response because it was a way of keeping faculty and attracting faculty to meet the really big demographically driven enrollment demand.

Mr. **Packard**. I am aware that there is a vote pending, Mr. Chairman. Let me ask one short question, and anyone can respond.

Each of you have alluded to the shortages of new scientific replacements in this country. Is there the possibility that the minorities and the women, there being a trend for them more and more to move into the scientific world than historically in the past, that they may pick up that void?

Dr. **Ramo**. The fraction of women in the population and the nature of science and engineering, what we know about the lack of any essential difference in talents based upon there being two sexes, all of that suggests that if we did the right things about incentives, role modeling at an early age, scholarships, fellowships, a number of programs, most of which are obviously the kinds of things that you would do if you were serious about it—and it would all cost some money, an investment in the future—there is a chance of increasing by 10, 20, 30 percent.

A similar thing, but a more difficult problem, I think, has to do with bringing minority groups in a similar way. The talent available today in age 5- to 15-year-olds, if properly put into a system to attack that problem seriously, not in a trivial and minor token way, should have the potential of giving us a very substantial increase.

Dr. **Nacht**. Could I respond to that as well? I personally do not believe that large numbers of women and minorities will rush forward to take up the slack unless there are specially earmarked programs. I mean, I still think that today it is more appropriate, if you will, in sociological terms for a male student to study computer science and have a woman study English literature, and when you have the other way around, you ask questions: Why is the guy studying English literature and sort of screwing around, and what is so special about this woman that she is studying computer science? I think, unless you have very specially earmarked programs with quite a lot of funding and push behind them to break down those stereotypes, no, I don't believe that women and minorities will rush forward in large numbers.

Mr. **Packard**. I thing *A Nation at Risk* has certainly pinpointed some of the same concerns that we have heard here this morning in regard to the declining educational quality in terms of science, math, foreign language, and some of those things that we have talked about this morning. I enjoyed very much the testimony of the witnesses.

Mr. **Fuqua** [resuming as Chair]. Mr. Mineta.

Mr. **Mineta**. No further questions.

Mr. **Fuqua**. I want to thank our panelists for being with us this morning. It has been very helpful.

This concludes our Science Policy Task Force hearings on "Scientists and Engineers: Supply and Demand."

Our next set of hearings will be on the impact of science on the information age. That will begin on September 10.

The meeting stands adjourned.

[Whereupon, at 12:09 p.m., the task force recessed, to reconvene at 10 a.m., Tuesday, September 10, 1985.]

APPENDIX 1

Revised Testimony by Daniel Kleppner, Professor of Physics, Massachusetts Institute of Technology on Supply and Demand of Scientists and Engineers

I appreciate this opportunity to discuss with the Task Force on Science Policy some aspects of manpower in physics. The subject is important because physics is important to all of us. This Nation's accomplishments in physics have enriched our understanding of Nature and advanced the welfare of people everywhere. Physicists contribute to national programs such as energy and defense, and to a wide variety of industrial programs, in addition to pursuing basic research. Furthermore, physics is a central science that contributes concepts, techniques and scientific manpower to the neighboring sciences, to engineering and to medicine. Currently, approximately thirty percent of the new Ph.D.'s in physics pursue careers in these other disciplines. Thus the health of the supply of Ph.D. physicists has ramifications not only for physics but for many other fields. For these reasons, the supply and demand of physicists in the future is of vital concern to the Nation.

A statistical and demographic study, The Education and Supply of Physicists (to be referred to as "the manpower study"), has been carried out by the American Institute of Physics Manpower Statistics Division for the forthcoming NRC-NAS Physics Survey. A draft is attached as a supplement. Although the manpower study has not yet gone through the Academy review process, I believe that it provides a well informed discussion of the data and their interpretation. It is to be noted that the projection of a similar study prepared for the last physics survey, the Bromley report published in 1972, accurately projected the overall physics employment figures to the present. This is an impressive achievement in view of the rapidly changing conditions in the 1970's.

I would like to summarize the salient features of the manpower study, and then to comment on them from my personal perspective.

MAJOR FEATURES

Ph.D. production. The annual Ph.D. production climbed from 600 in the year 1960 to a peak of 1545 in 1970. It plummeted during the 1970's and leveled at about 950 by 1980. The rate appears to be starting to climb slowly. Projections for the year 2000 range between 1000 and 1100 Ph.D.'s per year (see Table S2-8). A striking demographic feature is the increasing rate of foreign-born graduate students (Table S2-7). In 1970 less than 20% of the first year graduate students were foreign born: by 1983 the fraction increased to 40%. The projections for the turn of the century suggest that about half of our Ph.D. production will consist of foreign-born students.

Academic Employment. There have been tumultuous changes in academic employment as the rapid expansion in the 1960's abruptly terminated at the end of the decade. As a result, a middle age "bulge" has developed that dominates the future academic openings. The retirement rate will soon start to climb (Tables S2-4 and S2-5) and the number of tenured academic openings in universities is expected to increase steadily through the end of the century. The median faculty age will continue to increase during the early 1990's but, as Table S2-6 shows, before the end of the decade it will start to fall precipitously.

Demand Scenarios in Industrial and Other Non-Academic Sectors. The majority of the employment opportunities for Ph.D. physicists in the immediate future will continue to be in industry, Government laboratories and nonprofit organizations. Sixty percent of the currently employed Ph.D. physics work in these organizations: approximately half of them work directly in physics. The manpower study has projected the employment demand for a variety of conditions ranging from conservative economic growth with low outmobility of physicists to other fields, to moderate growth and moderate outmobility. The results are summarized in Table S2-6.

Summary - the Demand-Supply Balance. The manpower study concludes that there should be an approximate balance between demand and supply for Ph.D. physicists through 1991, but that later in the decade the supply of new physicists may not match the new openings (see Fig. S2-9). However, the study comments that the divergence between supply and demand may be greater than indicated because it does not include projected increases in neighboring scientific and engineering areas where physicists have always made important contributions. Thus, the projected balance between demand and supply through the early 1990's is described as "precarious". By the end of the enxt decade, the Nation's need for physicists is expected to exceed its supply.

COMMENTS

I would like first to respond to the Chairman's inquiry as to how my own field - Atomic, Molecular and Optical Physics - is faring in the current job market and what future trends are anticipated. The demand for Ph.D. physics in this area is high, largely because of the impact of lasers and the growth of modern optics. There are jobs available in all three principal sectors - academic, government laboratories and university laboratories. In viewing these employment needs, however, it is important to recognize that physicists are a flexible breed, and that many physicists will readily move into new research area if the intellectual challenges and/or employment opportunities are compelling. To cite two personal examples: One of my students whose Ph.D. research was in low temperature physics took an industrial position to develop laser gyroscopes. He has been very successful, notwithstanding that he had absolutely no previous experience with lasers. Another student whose research was on atomic structure accepted a position developing new techniques for physiological analysis and medical testing. He is also doing very well. These are by no means isolated instances: training in physics provides students with the ability to pursue any number of careers in government and industrial laboratories, and physics has traditionally served as a feeder for the other sciences.

A healthy community of physicists is an essential resource for the Nation regardless of the particular areas in which the physicists have been trained. This was demonstrated in World War II by the ease with which physicists with diverse backgrounds moved into new research areas to carry forward the Manhattan Project and the development of radar at the M.I.T. Radiation Laboratory. The influx of foreign physicists in the 1930's provided a major component of that physics community. After World War II the United States assumed pre-eminence in physics and we no longer had to rely on foreign-born talent. As the data in the attached manpower study indicate, however, the number of U.S. graduate students has dropped and we are increasingly relying on foreign-born students to meet our manpower needs. In the past, approximately half of these foreign-born students remained in the U.S. We are in a highly vulnerable situation because any change in this foreign student retention rate would have large leverage on our scientific manpower supply. Furthermore, foreign-born physicists are generally ineligible to work on military-related research. The decreased size of the U.S. enrollment in our graduate programs is, I believe, an ominous situation.

I believe that the overall balance between supply and demand in physics is a more critical concern than the particular areas in which students carry out their Ph.D. research. For example, the current production of Ph.D. optical physicists per year is barely fifty - not nearly enough to satisfy the Nation's current and projected industrial, government and academic needs. However, for the present we do not have an employment crisis in this area due to the outflow of physicists from other areas, as in the case cited above.

Behind the statistics of the education and manpower study one can sense qualitative changes that threaten our ability to sustain the quality of Ph.D. education in the U.S. In particular, many universities are finding it increasingly difficult to find fully qualified candidates for their junior faculty positions. In experimental condensed matter physics these universities report a severe shortage. Condensed matter physics is a unique field in that it possesses major industrial resources for basic research. In former times the most promising young scientists would choose careers from among industrial laboratories such as Bell or IBM and the universities. This is no longer the case. Even the leading universities report that they can no longer compete with industry for the best talent.

The shortage of outstanding faculty candidates in condensed matter physics is not simply a result of the industrial competition: that has always existed. The erosion of faculty salaries is an increasing concern, but an overriding problem is that many young scientists feel that they can no longer look to the universities to provide the environment required for forefront research. They see that our university laboratories are poorly equipped, that their professors must struggle to carry forward research without adequate support and spend their time hunting for money rather than devoting themselves to research and teaching. They see a situation in which the university groups are losing their ability to compete in research with industrial laboratories and laboratories abroad.

Today it is not unusual for some of our leading universities to search for several years in order to fill a junior appointment. This is ominous, for if the universities are already experiencing shortages of outstanding faculty candidates, then the probability is high that in the 1990's when new faculty positions proliferate due to the rapid increase in retirements, there will be a severe shortage of qualified candidates.

There is wide concern throughout the academic community in the United States about sustaining the quality of education and scholarship. My own university - the Massachusetts Institute of Technology - has recently formulated a long range plan that addresses these issues. The Institute intends to improve the atmosphere for academic research by generating more internal support - particularly support for young faculty members - and increasing faculty salaries. However, the level and nature of federal support is of overriding importance. To quote from MIT's long range plan

> Since World War II, as the research universities grew, research and scholarship advanced and grew more complex, requiring a level of funding which in large part could only be provided by the federal government. As the level of support has grown, many of the federal offices that fund university research have retreated from the original, unwritten compact: that the government would support university research to make possible the education of successive generations of students and the preservation and growth of American scholarship, science, and basic technology.

The United States cannot maintain the level of physics that is essential for its national needs unless this unwritten contract is restored. I fervently hope that the Task Force on Science Policy is successful in this enterprise.

SUPPLEMENT
EDUCATION AND SUPPLY OF PHYSICISTS

The many opportunities for achieving major advances in physics research during the coming decades are discussed elsewhere in this overview report. While international cooperation and competition will continue to simulate the scientific enterprise, the maintenance of a U.S. leadership role in physics is important both for the vitality of physics as a field and for the technological position of the country as a whole. Asserting such leadership and meeting the scientific challenges and opportunities of the future clearly call for a strong base of highly trained individuals. This supplement describes the changing patterns in the supply and employment of physicists and poses questions concerning the availability of these manpower resources in the future.

The events of the past two decades have left us with an aging academic community, a smaller core of physicists regularly engaged in basic research, and a continuing high outflow of physics Ph.D.s to related areas of science and engineering. While graduate enrollments in physics began to increase in the 1980's, most of the increase reflected the rapid growth of the foreign student component. The continued decline in the number of U.S. physics graduate students, coupled with a low retention of Ph.D.s in physics, leads us to expect only minor increases in the physics labor force in the near future.

By the middle to late 1990's, greater than usual retirements, based on the large number of entries in the 1960's, are expected. It is possible that the supply of entrants into the physics labor force could decline at the very time when retirements will be most numerous. Although alarmist cries of shortage and pleas for a return to the high production levels of graduates during the late 1960's would be inappropriate, concern over the effects of a potentially diminishing labor force is warranted.

In the following sections, we describe the major aspects of the current situation and the issues they highlight, including an analysis of the contributory events of the past two decades. We conclude the supplement by projecting physics manpower in the coming decades. Because the production of highly skilled physicists is a long-term process calling for extensive lead time, developing such projections takes on added import.

S2.1 Producing Trained Young Physicists - A Historical Overview

Initial decisions affecting (or precluding) later careers in science are typically made in the early teen years. Students who do not enter the advanced science and mathematics sequence at the secondary-school level are unlikely to be prepared for college-level science courses. They are even less likely to consider majoring in physics. In the United States, however, less than half of secondary school students take more than 2 years of science and mathematics. A much smaller proportion (less than 20% of 1980 graduating seniors) is exposed to physics. The value of even that limited exposure is being questioned in light of the shortage of qualified mathematics and science teachers. Many of the competent teachers have left for more prestigious and remunerative job opportunities, while the number of new science teachers being trained has declined severely.

This deteriorating condition of precollege science and mathematics education has long been of concern to the physics community. By the 1980's it had become a national concern.* The crisis in secondary-school education raises serious questions about the future scientific literacy of the Nation and the development of the needed pool of potential scientists.

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*See, for example, A Nation at Rest, A National Commission on Excellence in Education, 1983, and Teacher Shortage in Science and Mathematics, NIEE, 1983.

The training of a professional physicist is both lengthy and selective. Only a small proportion of the individuals exposed to physics at the college level actually major in physics. A still smaller number enter physics graduate study and emerge from 4 to 9 years later with a Ph.D. This core of individuals constitutes a unique group with a high level of intellectual ability and an array of flexible, sophisticated skills. They are a precious national resource. It is this group that will be responsible for the continuing physics research effort; for the training of the next generation of students, researchers, and teachers; and for providing the talent that offers important stimulation to a wide variety of related scientific and engineering disciplines.

Following a rekindled interest in the physical sciences brought on by Sputnik and increased Federal support, the total number of physics graduate students climbed rapidly during the 1960's, rising to over 15,000 in each of the last 3 years of the decade. In 1969-70, Ph.D. production peaked at 1545 (Figure S2-1), a 148% increase since the beginning of the decade.*

Employment opportunities in academe were bright during the early 1960's because of the marked upsurge in the number of students and increased Federal grant money for research. New physics Ph.D.s quickly filled the assistant professor ranks. There were a large and ever-increasing number of positions in research and teaching. Although it was difficult to believe at the time, such high rates of expansion could hardly be expected to continue indefinitely.† They did not. Towards the end of the decade when the physics student body was approaching its peak, harbingers of difficulties ahead began to appear. Federal funding for basic research slowed with the Nation's heightened

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*Data are derived from AIP's annual departmental surveys of enrollments and degrees. Figures may differ slightly from those obtained from othe sources, e.g., NAS and NSF. Nearly 100% of physics departments have traditionally responded to these annual AIP surveys. Data from missing departments are estimated on the basis of the previous year's responses.

†Physics: Survey and Outlook, NAS, 1966.

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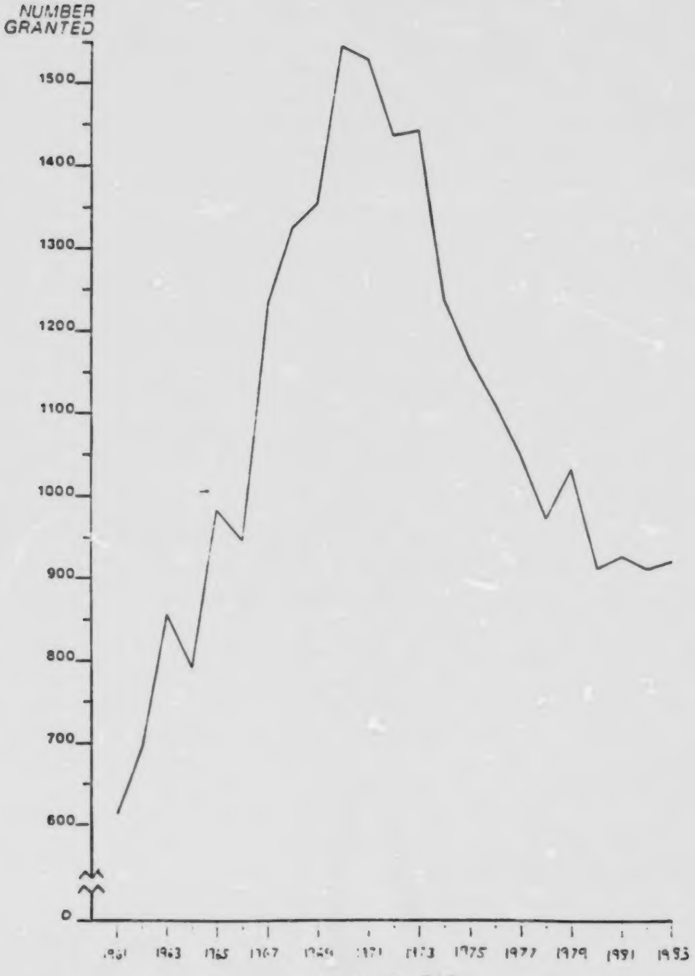

Figure S2-1. Physics Doctoral Degrees Granted, 1961-1983.

involvement in the Vietnam War.* The Mansfield Amendment had the effect of curbing basic research support from many of the traditional mission agencies, and the National Science Foundation was unable to assume fully the burden of support. New academic positions diminished in number, and the economy (which had not been particularly robust), presented only limited alternative job opportunities.

When the large new classes of physics Ph.D.s entered the employment marketplace at the beginning of the 1970's, traditional opportunities had nearly vanished. Many more Ph.D.s than usual took temporary postdoctoral positions, hoping to wait out the economic doldrums. Despite the unfavorable job market, most new physics Ph.D.s did find science-related positions, although not always long-term ones in physics research. The dashing of expectations for traditional university research careers in the first half of the 1970's brought bitterness to some and a changed perspective to many others.† Horizons were altered; more attention was paid to the varied work activities one could perform with a physics Ph.D. As the decade progressed, industrial employment grew, both in physics and in related science and engineering areas. Physics Ph.D.s adjusted their expectations and took advantage of the changing opportunities.

While new employment avenues began slowly to expand, degree production in physics plummeted. Bachelor's degrees had already begun to decline by the late 1960's; Ph.D.s soon followed, dropping from over 1500 at the beginning of the 1970's to little more than 900 by the end of the decade. This reaction to the difficult market conditions of the early 1970's eased the employment situation for the new Ph.D.s emerging in the middle to late 1970's. Job offers increased, and by 1980, only 2% of the Ph.D.s did not have job offers at the time their degrees were granted, compared to 25% at the start of the decade.

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*See Chapter 3 on research funding for further details.

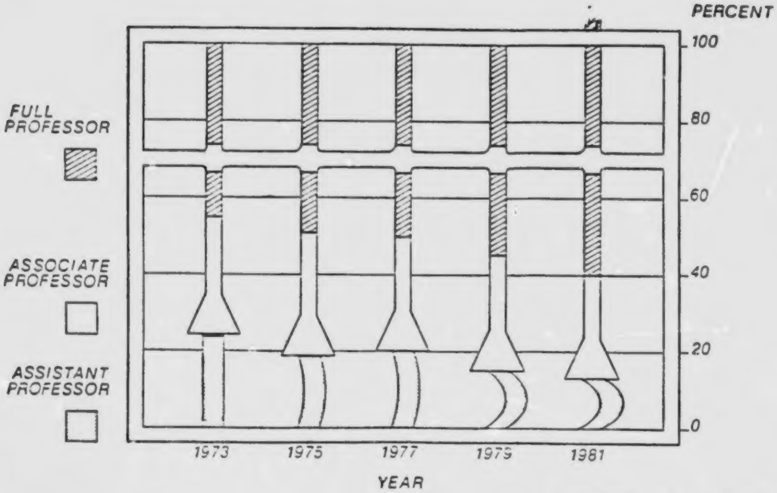
†The Transition in Physics Doctoral Employment, 1960-1990, APS, 1979.

This steep decline in physics degree production was occurring at the same time that the overall number of students in postsecondary-school education was rapidly growing. The products of the extended demographic "baby boom" of the 1950's, encouraged by the availability of educational loans, filled the colleges in the 1970's. Many students entered the biological and social sciences, but few of them majored in physics. Ph.D.s in physics, in fact, represented only 7% of all natural science and engineering doctorates in the late 1970's, down from the 11% figure which had been relatively constant for several decades. Although such a shift might have augured well for the competitive employment position of new physics-degree holders, it raised concern about the availability of future human resources in physics.

Academe was the one area where employment opportunities for new physics Ph.D.s had not altered by the beginning of the 1980's. The large number of young physicists who had swelled the ranks of the assistant professors in the 1960's were now tenured but still far from retirement. In 1980, assistant professors represented only 14% of academic physics staffs, a lower percentage than in any other scientific discipline (Figure S2-2). With few senior positions opening, even some of these assistant professors would not receive tenure. The effects of this "missing generation" of young academics are reflected in the marked aging of university physics department staffs from a median age of 38 in 1973 to 44 in 1981. This brief history of the past two decades of physics Ph.D. production and the labor market provides a background for discussing the important human-resource issues facing physics in the 1980's.

S2.2 Enrollments and Degrees: The Prolonged Decline

As noted, physics Ph.D. production declined rapidly throughout the 1970's, dropping to the low 900s by 1980, and hovering at that level since. In 1980 the first-year physics graduate student enrollment was 2439, down 44% from the middle 1960's. Graduate physics enrollments had finally bottomed out; 1981 saw the first rise in enrollments in 15



SOURCE NAS unpublished data on Physics PhD's

Figure S2-2. Academic Rank of Physicists Employed in Universities and Colleges, 1973-1981.

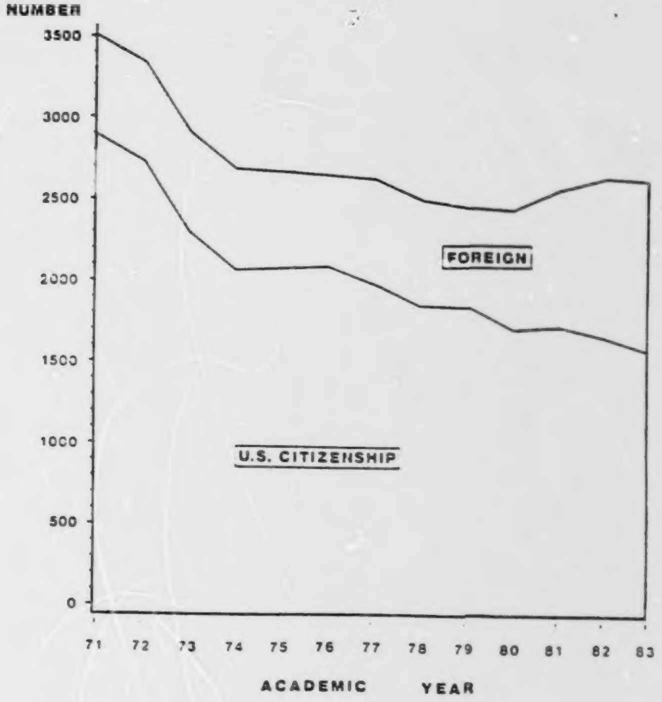
years. While it would be another 5 to 6 years before these increases could be reflected in Ph.D. production, an eventual turnaround seemed on the horizon.

S2.2.1 U.S. and Foreign Composition

Detailed analysis of enrollments, however, pointed up a new phenomenon. In the 1970's foreign students had formed about one-fifth of physics graduate students, or about 600 new foreign nationals a year. As the total number of first-year physics graduate students reached its nadir in 1980 and then began to increase, a major change in the citizenship composition of these students was also occurring. By 1983, over 1000 of the first-year physics graduate students were foreign citizens--40% of that entering class. U.S. university physics departments were drawing students from many countries, providing particular opportunities for students from the less-developed countries in Asia and the Middle East. This influx of foreign students, however, clouded another trend. The decline in first-year graduate enrollment of U.S. citizens in physics did not, in fact, bottom out in 1980; it continued through 1983 (Figure S2-3).

If there had previously been concern about the availability of highly trained physics manpower in the U.S., these data only accentuated the concern. What lay behind this continued decline in U.S. graduate students? Although most academic opportunities remained tight, the general employment situation for new physics Ph.D.s was healthy. Job offers were strong, and starting salaries were high. Were the front-paged breakthroughs in the biosciences, the new technology excitement of computer science, and the financial rewards of the professions drawing bright potential physics students away? Such changes in student career directions could have a major impact on a comparatively small area of concentration like physics.

In 1984, first-year foreign graduate students continued to increase; however, U.S. enrollments for the first time in many years increased even more. Although 1985 saw a flattening of these trends, the current hope



SOURCE: AIP

Figure S2-3. First-Year Graduate Physics Students by Citizenship, 1971-1983.

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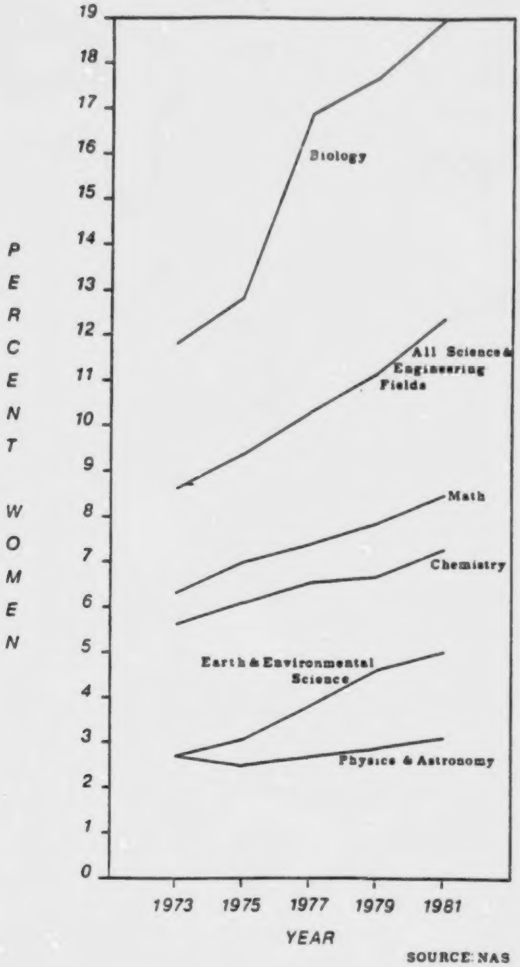
in what had been a long time in U.S. first-year enrollment provided at least a temporary sense of relief to the physics community. (Sic.)

S2.2.2 Women and Minorities

Despite intensified efforts on the part of professional societies in physics and of related women's groups, women still represent only a small proportion of Ph.D. physicists (Figure S2-4), approximately 3%, the lowest among the major scientific areas. New physics Ph.D.s include a higher proportion of women, but the actual number of doctorates awarded to women has not changed since the middle 1970's--approximately 65 per year. In most science and engineering areas, increased degree production has reflected the growing participation of women. Enrollment of women in the formerly male bastions of engineering and computer science, particularly at the undergraduate level, has skyrocketed. The same cannot be said of physics.

The reasons for the continuing underrepresentation of women in physics are not yet fully understood. Women constitute the major untapped future resource for the physical sciences and engineering; nowhere is that more true than in physics. Whether one is thinking of the future development of the field, or of equal access by all segments of the population, the minimal participation of women in physics remains a major concern.

If the representation of women in physics is low, the representation of indigenous U.S. minorities, i.e., Blacks, Puerto Ricans, Mexican Americans, and Native American Indians, is even lower. They make up less than 1% of the physics labor force; total production at all degree levels remains low. Full representation is found only among Oriental Americans. This is a problem shared throughout the science and engineering community. Some inroads have been made at the bachelor's level in fields such as engineering and chemistry, and probably in computer science. Physics, with few direct entry-level positions, has seen no increase in the representation of indigenous minorities. If anything, the number may be decreasing.



SOURCE: NAS

Figure S2-4. Women as a Proportion of All Doctoral Scientists by Selected Fields, 1973-1981.

S2.2.3 Declining Enrollments In Physics Subfields

The steep decline in physics Ph.D. production affected most of the major subfields of physics during the 1970s (Table S2-1). Degrees in Solid State Physics, Elementary Particle Physics, Nuclear Physics, and Atomic, Molecular, and Optical Physics dropped to less than half of their peak early-1970s levels by the beginning of the following decade; they have remained relatively stable since. Any continued erosion in subfield degree production may present threats to the research vitality of an area and could be a cause for concern in the entire physics community.

While degrees in Plasma Physics and Astrophysics also declined from their peaks in the early 1970's, the drops were not as precipitous. Only in Optics, one of the most applied of the major physics subfields, could a countertrend be observed; here, Ph.D. production doubled between 1971 and 1981. A similar increase was occurring in Medical Physics, although this area was not yet being monitored by the National Research Council.

S2.3 Retention of Physics Degree Holders - Mobility

Whether or not one thinks of physics as the "Queen of the Sciences," it is clear that physics has traditionally trained practitioners for other disciplines: at the bachelor's level for engineering, at the master's level for education and business, and at the Ph.D. level for a multitude of developing science and engineering areas. More than any other scientific discipline, physics has sent its Ph.D.s to related disciplines in order to serve society's growing technological needs.

Much of the outmobility of physics Ph.D.s has been into engineering and interdisciplinary areas such as geophysics, materials research, and biophysics, but Ph.D. physicists also work in a broad span of other areas ranging from chemistry to the biosciences. Some of this mobility occurred within academe where physicists teach and conduct basic research in related science and engineering departments. Most of it, however,

Table S2-1

Number of Physics Doctorates by Subfield, 1969-82

Subfield	Academic Year 1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Solid State	360	402	442	393	400	351	319	282	257	243	243	202	250	235
Elementary Particle	220	258	278	198	222	148	124	128	138	135	119	117	117	118
Nuclear Structure	188	212	227	234	182	144	130	96	93	77	103	73	62	53
Atomic & Molecular	127	152	124	150	122	120	138	116	105	88	72	69	65	96
Plasmas	61	85	86	93	74	57	53	75	72	68	62	59	65	69
Astrophysics	55	63	54	66	67	77	71	72	57	74	57	69	59	50
Optics	16	30	25	31	33	26	33	50	31	33	46	43	54	42
Acoustics	11	22	20	20	15	11	12	9	12	14	13	23	13	11
Other	369	385	425	387	411	344	353	329	321	270	335	278	280	287
TOTAL	1407	1609	1681	1572	1526	1278	1233	1157	1086	1002	1050	933	965	961

Source: NAS

occurred in the industrial sphere where applications of physics research easily moved across disciplinary barriers.

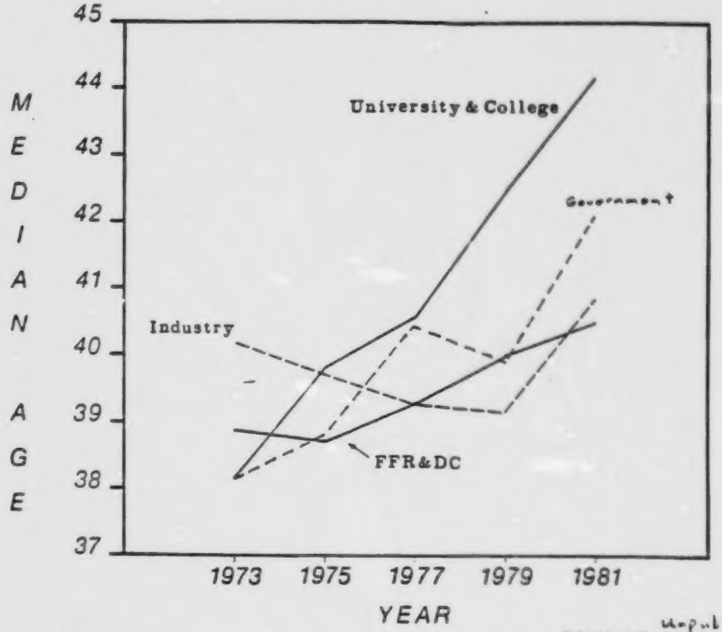
While patterns of high outmobility have been typical of physics and actually alleviated potential problems during periods of surplus, one must examine their impact during periods of dwindling supply. In the early 1970's, 30% of Ph.D. physicists were working outside of physics. As the economic support for physics research declined and alternative opportunities arose, the proportion increased to approximately 40%. Since the middle 1970's, employment opportunities in physics have improved; however, physics continues to provide needed skilled resources to other science and engineering areas at the same high rate. As the 1980's began, a large number of Ph.D. physicists were moving into the growing areas of systems and electronic engineering and computer science. In 1981, 27,000 physics Ph.D.s were employed in the United States; 10,400 of them were working in nonphysics areas.

Physics will certainly continue to provide many of its well-trained researchers to the new, growing areas of the future. Concern, however, may arise when this high level of outmobility is coupled with a decline in the supply of new physics degree recipients--the dominant pattern of the past decade.

S2.4 An Aging Community

The declining physics Ph.D. production during the 1970's, coupled with the departure of many young Ph.D.s to neighboring science and engineering areas, has produced a slow aging of the physics community over the past decade. This aging was most marked in academe where opportunities for young physics faculty remained blocked by the highly tenured-in staff at most physics departments and the lack of funds for staff expansion (Figure S2-5).

In the early 1970's, physics faculties, at a median age of 38, may have been preternaturally young, reflecting the heavy influx of new



SOURCE: Unpublished NAS Data

Figure S2-5. Changing Median Age of Physicists by Employment Sector, 1973-1981.

Ph.D.s during the previous decade. This was certainly not true in 1981, by which time the academic physics community had aged by an average of 6 years to 44. They were not only the oldest group within the physics community, but they were also older than academics in other science disciplines (Table S2-2). Most of the full professors who by 1981 made up the majority of the academic physics staff were still, however, more than a decade away from retirement. Thus, additional aging is expected in academe through the 1980's, although some expansion of opportunities appears likely as retirements slowly begin to increase.

The universities provide the major stimulus for the important basic research that drives the development of the entire field. An aging faculty raises a number of issues. The most obvious one is the lack of academic opportunities for young physics Ph.D.s.* At the predoctoral, postdoctoral, and junior faculty levels, young physicists have traditionally made major creative contributions to forefront basic research in physics.† The full effect of these contributions frequently does not appear for several decades; thus, many of the accolades of the 1980's have their source in the research activities of young physicists in the halcyon decade of the late fifties and early sixties. The relative absence of young researchers from today's academic scene is a cause for concern about our ability to pursue effectively the opportunities that lie ahead in physics.

The increasing predominance of the older physics faculty member brings an additional concern to the fore. Physics has traditionally attracted a very small number of women and indigenous U.S. minorities. Cultural attitudes towards women and minorities in the sciences and other areas dominated by white males have been shifting; however, a paucity of role models exists. To what extent these attitudes are reflected in the

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*Physics Careers, Employment and Education, AIP Conference Proceedings Number 39, 1978.

†See, for example, Jonathan R. Cole, Stephen Cole, Social Stratification in Science, University of Chicago Press, pp. 107-109, Chicago, 1973, and Robert K. Merton, The Sociology of Science, University of Chicago Press, Chicago, 1973.

Table S2-2

Age Distribution of Full-Time Employed Ph.D. Faculty Members by Selected Departments, Spring 1980.

FIELD	AGE (Percent) Under 30	30-39	40-49	Over 50
All Fields	5	33	32	30
Physical Sciences	3	28	36	33
Chemistry	4	30	34	31
Geology	5	29	34	31
Physics	2	25	38	35
Engineering	6	28	36	29
Chemical	9	26	32	32
Civil	4	31	38	27
Electrical	6	28	36	30
Mechanical	6	26	38	30
Mathematics and Computer Science	8	38	30	22
Mathematics	8	37	31	24
Computer Science	12	43	26	18
Biological Science	3	35	29	33
Biology	3	35	30	31

Source: National Science Foundation

aging academic physics community is unclear. The importance for the future of actively reaching out to these potential physicists from nontraditional backgrounds, however, is clear; accomplishing such communication may require skills that many of the older physics faculty have not yet developed.

Physicists have also aged in other economic spheres. Except for the in-house Government laboratories where funding cutbacks had been particularly large, however, such aging was minimal in contrast to that observed in the universities. In fact, the median age of the population of physicists employed in industry decreased during the 1970's as young physicists sought out new avenues of employment both within and outside physics.

S2.5 Changing Patterns of Employment

Patterns of physics employment underwent major changes in the past decade. In the early 1970's, half of all physics Ph.D.s were academically employed. By 1981, the proportion had dropped to about 40%. Academic growth in physics during the decade was sluggish, with teaching staffs actually declining in size through 1979.

Employment of physics Ph.D.s in industry, on the other hand, burgeoned from under 5000 Ph.D.s in 1973 to over 8500 in 1981, representing in the latter year nearly one-third of all employed physics Ph.D.s. The steady growth in industrial employment of physicists reflected the favorable climate in that sector as well as the closing of academic doors. Although some of these new industrial opportunities were in physics itself, the areas of highest growth were in related sciences and engineering. The physicists who pursued these openings were, in general, primarily involved in development and design, and secondarily in applied research. Basic research has generally played a minor role in industrial employment. The proportion of industrially employed Ph.D.s engaged in basic research continued to decline over the period, falling to below 10% by the end of the 1970's.

Employment in the national laboratories, which had remained virtually unchanged during the otherwise expanding 1960's, increased steadily through the 1970's.* These laboratories offered special opportunities, in addition to providing a home for some of the basic physics research which had traditionally been carried out in the universities. However, the major increases occurred in the areas of applied research, as the national laboratories took on more diversified missions. In fact, by the beginning of the 1980's, a shift in emphasis at these laboratories from basic to applied research had occurred. Employment at in-house Government laboratories showed only minimal growth throughout the decade.

These changing patterns of employment, particularly in the industrial sphere, allowed for the absorption into the economy of the unusually large number of new physics Ph.D.s who emerged into the marketplace during the early 1970's. These Ph.D.s were not always doing what has been traditionally termed physics, but relatively few of them experienced any prolonged unemployment. In 1970, when Physics in Perspective was being developed, in the midst of a period of increasing hardship, the National Academy of Sciences report noted:

> The 1970's have begun with recognition of a critical employment situation and the realization that the traditional patterns of employment in physics are changing. If physicists understand the nature of this change, are flexible in their attitudes and will undertake careers not only in physics, but in related disciplines and specialties that also offer challenging problems, the outlook for the future could be more encouraging than was first assumed.†

Physics Ph.D.s appeared to have followed this dictum well. The entry of young physicists into the growing areas of applied research and technology provided an important dynamic for the development of a multitude of exciting new applications of physics research, from telecommunications through medicine.

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*National laboratories, such as Brookhaven and Fermi Laboratories, are completely funded by the Federal Government, but are administered by universities, industry, and nonprofit groups.

†Physics in Perspective, NAS, 1972, p. 856.

Basic physics research did not enjoy the same healthy expansion, although a core of dedicated researchers did manage to weather the vagaries of an uncertain decade and continued to carve out new avenues of exploration at the forefront of physics. If basic research is to remain vital through the rest of the 20th century, it is important to guard against any further erosion in this dwindled pool of human resources, and to encourage the infusion of new talent.

S2.6 Projections

Projections of demand and supply are crucial to any understanding of future balances in scientific manpower. These projections are an attempt to understand what appears most likely to occur to the physics labor force under different assumptions regarding expected changes in demand and supply. They should not be treated as predictions, but rather as probable outcomes under given scenarios. Table S2-3 summarizes the critical parameters of the demand and supply models.

S2.6.1 Demand Projections

The demand for physicists in the future involves both replacements for current positions and growth, both directly in physics and indirectly in related disciplines. Our concentration here will be on Ph.D. physicists working in physics. Because the expected demand scenarios in academe and outside it are quite different, they will be treated separately. Scenarios cover the period 1981-2001.* Estimated figures are presented for cumulative 5-year periods in order to minimize unpredictable year-by-year fluctuations.

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*The NAS biennial surveys have been used both to establish the employment patterns of physicists in the base year 1981 and to estimate mobility rates. 1981 is the last year for which data from the NAS biennial surveys are available.

Table S2-3

Parameters in Demand and Supply Scenarios

Parameters in Demand Scenarios

- Demand for physicists in universities and colleges
  - Openings, no growth
    - Death and retirement: age structure
    - Outmobility from academe
  - Patterns of replacement
    - Service course loads and demographics: future enrollments
    - Promotion rates
    - Age and tenure status of new hires
- Demand for physicists in industry, Government, and Federal laboratories
  - Openings due to replacement
    - Death and retirement
    - Outmobility from physics
  - Openings due to growth
    - Economic growth, R&D, and defense spending

Parameters in Supply Scenarios

- Physics Ph.D. Production
  - Demographic age factors and patterns of enrollment in higher education
  - Perception of technological opportunities and choice of major
  - Retention in the educational system
  - Entry of foreign graduate students
- Available supply of new physics Ph.D.s
  - Net migration of foreign nationals
  - Immediate outmobility to other fields

Academe. The academic employment of Ph.D. physicists has undergone tumultuous changes during the past two decades. Few labor force analysts writing during the expansionary period of the 1960's envisaged the tight academic market that would dominate the physics scene throughout the 1970's and into the 1980's.* These abrupt changes have produced a unique age structure: In 1981, 40% of university physics faculty were over 50 years old, while another 40% were between the ages of 40 and 49. This middle-aged "bulge" has a major effect upon any projections of future academic openings.

Death, retirement, outmobility, and promotion rates take on added importance when such large numbers of individuals are concentrated in the older age groups. We are assuming constant age-specific death rates for our academic professoriat, based upon current TIAA-CREF mortality schedules for males.† However, while the age-specific death rates remain constant, the numbers of probable deaths and potential openings will escalate as the middle-aged bulge of 1981 ages.

Retirement practices are not as clear-cut. The laws deferring mandatory retirement to age 70 were extended to academe in 1982. However, TIAA-CREF officials do not yet see any evidence of a further shift toward delayed retirement. If anything, they see some increased tendency for academics to seek early retirement. Thus our model allows for some early retirement and for half of the physics faculty members still working at age 65 to remain employed beyond that age. The combined effects of death and retirement should thus bring a dramatic increase in university employment opportunities in the 1990's.

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*Alan Cartter was less sanguine than many of his colleagues about the continuing expansionary needs of the future, but his voice was not the dominant one at the time.

†TIAA-CREF is the dominant retirement annuity fund for academics. Thus, their mortality schedules are most appropriate for use here. They will also be used when dealing with nonacademic physicists, since general mortality schedules would indicate death rates abnormally high for professional workers. In a community which is 95% male, the dependency on male death-rate schedules should not need need comment.

Academic positions can also be freed by mobility. However, few tenured older faculty have left academe in recent years, and, conversely, not many senior-level physicists have been drawn into academe from industry or Government. Movement into and out of academe by younger researchers, on the other hand, is an elastic and volatile phenomenon closely related to promotion rates and the availability of permanent senior positions. While AAUP rules set maximum time periods for which one can remain in untenured positions, they do not establish minimum times. If shortages develop, promotion policies are perhaps the most manipulable in the system. The model focuses on expected future openings in the senior ranks as the best indicator of long-term employment opportunities.

In addition to replacement needs, academic openings can result from growth. Total faculty demand is, we believe, more tied to service course loads than to basic research needs. By the mid-1990's, the 18- to 24-year-old age group, from which college students are traditionally drawn, will decline by over 20%. How many of them will attend college and take physics is, of course, the central issue. If tomorrow's students continue to need a strong technological background, then it is unlikely that enrollments in traditional science areas such as physics would suffer as precipitous a decline. However, it is questionable whether they would move so counter to the overall expected decline in student bodies as to produce a demand for faculty growth. Thus, the following scenarios assume that there will be no real growth in academic physics faculties through most of the remainder of the century.

Demand Scenarios - Universities. Our projections for university physics demand involve the following three major scenarios. In each scenario, replacement positions refer to existing senior positions vacated through death, retirement, and mobility out of academe.

- All replacement positions are filled.
- 10% of replacement positions become unavailable.
- 20% of replacement positions become unavailable.

All three scenarios recognize the expected decline in traditional university students in the late 1980's and 1990's and incorporate some countervailing swing towards increased demand for service courses in physics and other hard sciences. We feel the second scenario, which assumes a moderate shift toward a more science-oriented student body, is the most likely. It should be recognized that any cuts in physics faculty will hit some institutions harder than others.

Under the three replacement scenarios, the median age of the university physics professoriat, 46.5 in 1981, can be expected to continue to climb by an additional 4 to 6 years through the early 1990's, peaking at somewhat over 50. Thereafter, a rapid decline in median age is expected as staff from the middle-aged bulge of 1981 begin to retire and young academics fill out the professorial ranks.

Figure S2-6 illustrates the probable ranges in future median ages based on extrapolations from past hiring and promotion practices. By 2001, professors under 40 will increase to between one-quarter and one-third of the total physics staff, not as high a proportion as was found in the early 1970's, but a more substantial base than is currently observed.

Demand Scenarios - 4 Year Colleges. Physics faculties at the 4-year colleges are considerably smaller in number, and their age structure is notably younger, than are their counterparts in the universities. Possible openings due to death and retirement through 2001 are thus relatively limited. We expect the declining number of traditional college-age students enrolling by the 1990's to have a dramatic effect on the physics programs at the 4-year colleges, many of which are even now experiencing financial difficulties.

We present three possible scenarios, ranging from a severe staff reduction of 30% to a more modest one of 10%. Technological opportunities of the future and the relevance of a solid physics background may pull college students into physics courses at a higher

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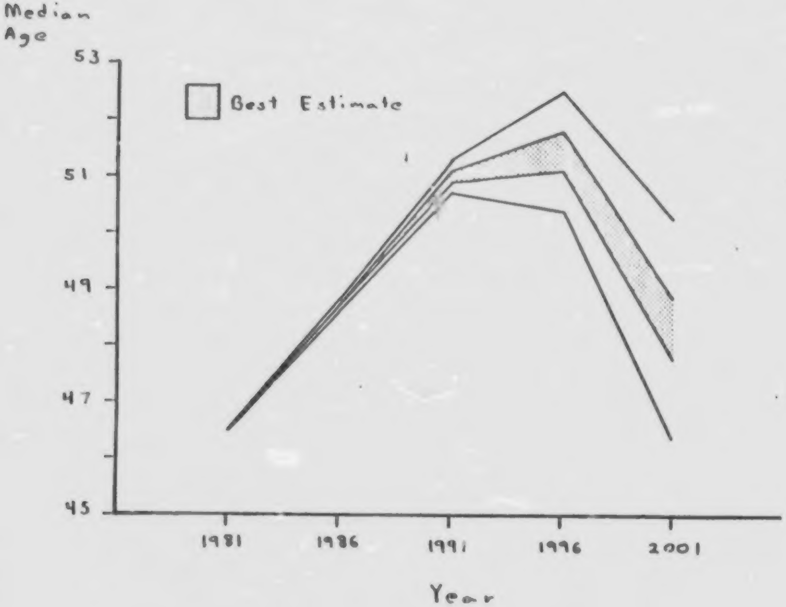

Figure S2-6. Projected Median Age of University Physics Professoriat at 5-Year Intervals, 1981-2001.

rate than currently observed. However, to achieve only minor staff reductions, physics departments at 4-year colleges will need to recruit more nontraditional students.

The accompanying tables for universities (Table S2-4) and 4-year colleges (Table S2-5) indicate the expected academic openings between 1981 and 2001 under the major scenarios outlined above. According to our intermediate scenario, tenured academic openings will increase steadily, swelling from 750 for the first 5-year interval (1981-1986), to nearly 1200 in 1996-2001. Whether new physicists will be available to fill these openings will be addressed later.

Demand Scenarios - Industrial and Other Nonacademic Sectors. Opportunities for physicists over the coming decade will derive primarily from openings in industry, Government laboratories, and nonprofit organizations, where 60% of Ph.D. physicists are currently employed. About half of these physics Ph.D.s are working directly in physics.

Since only 20% of these physicists were over the age of 50 in 1981, death and retirement will not be major sources of openings during the rest of the century. Most analysts, however project some growth, in contrast to the projections for academe. Highest growth is expected among small consulting firms and medical laboratories.* Growth is also expected in the larger electronics and communications industries where many physicists are concentrated. While Federal employment is not expected to be a major source of new positions, the national laboratories should continue to provide moderate growth in employment opportunities for physicists. We will use variations around the Bureau of Labor Statistics intermediate projections to describe expected growth in overall physics employment outside of academe.†

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*See, for example, Industry - Occupational Employment Matrix. Bureau of Labor Statistics data tape, 1980, and Problems of Small, High-Technology Firms, NSF 81-305.

†Occupational Projections and Training Data, BLS, Spring 1984.

Table S2-4

Projected Number of Physics Openings in Universities, Resulting from Death and Retirement of Senior Staff, 1981-2001.[a]

	ACADEMIC YEARS				
	1981-1986	1986-1991	1991-1996	1996-2001	Total 1981-2001
Number of Openings Due to Death and Retirement	769	911	1018	1119	3815
Number of Openings Filled by Replacement Scenario[b]					
Low	615	729	814	895	3053
Intermediate	692	820	916	1007	3436
High	769	911	1018	1119	3815

---

[a] Senior staff are defined as physics Ph.D.s employed as associate or full professors in universities. Figures for the base year 1981 were derived from unpublished NAS data.

[b] The high scenario assumes that university physics departments will attract undergraduate enrollment at significantly higher levels than at present and thus will experience no decrease in staff size. The remaining two scenarios assume that universities will attract undergraduates at higher rates than at present but not high enough to justify current professoriate levels. Thus, the low and intermediate scenarios reflect the hiring potential if 80 and 90% (respectively) of senior staff openings are filled.

Table S2-5

Projected Number of Physics Openings in 4-Year Colleges, Resulting from Death and Retirement of Senior Staff, 1981-2001.[a]

	ACADEMIC YEARS				
	1981-1986	1986-1991	1991-1996	1996-2001	Total 1981-2001
Number of Openings Due to Death and Retirement	114	154	243	299	810
Number of openings Filled By Replacement Scenario[b]					
Low	39	53	84	103	279
Intermediate	64	87	137	168	456
High	89	120	190	234	633

---

[a] Senior staff are defined as physics Ph.D.s employed as associate or full professors in 4-year colleges. Figures for the base year 1981 were derived from unpublished NAS data.

[b] It is assumed that the decline in the number of traditional age college males will adversely affect 4-year college staffs more than university staffs. In fact, the decline in undergraduate enrollment may result in the closing of physics departments in some 4-year colleges. The three scenarios (high, intermediate, and low) reflect the reduction of the total physics professoriate in 4-year colleges by 10, 20 and 30%, respectively. The data indicate the number of senior staff openings due to death and retirement that would be filled to achieve these reductions in overall physics staff.

We pose two basic scenarios for growth in nonacademic physics employment. The first scenario assumes a moderately paced economy reflecting nonacademic growth at approximately the levels that occurred during the 1973-1981 period. This growth would average 3% per year, which is consistent with the Bureau of Labor Statistics (BLS) intermediate projection for physicists through 1995. The second scenario assumes a somewhat slower-growing economy, reflecting a more conservative increase in nonacademic opportunities. Demand would be above replacement, but below that suggested in the prior scenario. This growth would average 2% per year. Based on expectations over the long term for an increasingly technological labor market calling upon sophisticated research and development skills, we feel that the moderate growth scenario is the most likely forecast.

Positions opened by physicists leaving the field are also an important source of future employment. Currently the net outmobility of physicists is nearly 1.5% a year. If the supply of physics Ph.D.s falls short of the demand, the level of outmobility may decrease despite a strong continuing pull into other fields. Thus the model poses two levels of net outmobility: moderate outmobility consistent with current levels, and low outmobility of approximately 1% a year.

Table S2-6 indicates the number of positions in physics expected to be open in the 1981-2001 period under these two basic scenarios. The potential demand for physics Ph.D.s in related areas of science and engineering is difficult to measure precisely because there is often only a fine line separating them from physics. Nevertheless, demand for physics Ph.D.s in these areas is also expected to increase in the next decade. Thus, there are several hundred potential nonphysics or interdisciplinary openings for Ph.D.s in addition to those described in the scenarios above.

S2.6.2 Supply Projections

Projections of supply depend upon a number of interdependent variables: the size of the age groups from which the supply is

Table S2-6

Employment Opportunities for Ph.D. Physicists Working in Physics Outside of Academe by Demand Scenario and 5-Year Groupings, 1981-2001.[a]

Conservative Growth (2% per year)	1981-86	1986-91	1991-96	1996-2001
Low Outmobility (1% per year)				
Replacement	803	939	1146	1362
New Openings	757	757	757	757
Total	1560	1696	1903	2119
Moderate Outmobility (1.45% per year)				
Replacement	963	1103	1305	1509
New Openings	757	757	757	757
Total	1720	1860	2062	2266
Moderate Growth (3% per year)				
Low Outmobility (1% per year)				
Replacement	803	960	1188	1428
New Openings	1136	1136	1136	1136
Total	1939	2096	2324	2564
Moderate Outmobility (1.45% per year)				
Replacement	963	1132	1364	1600
New Openings	1136	1136	1136	1136
Total	2099	2268	2500	2736

---

[a] The conservative growth rate indicates the number of openings in a slowly growing economy.

The moderate growth rate is similar to the increase in demand in nonacademic positions observed between 1973 and 1981. It is also consistent with the BLS intermediate scenario for growth in demand for physicists through 1995.

The low outmobility rate reflects the lowest level that outmobility is likely to reach.

The moderate outmobility rate reflects the current net mobility of physicists into other fields.

Replacement refers to openings due to death, retirement, and net outmobility.

New Openings indicate the number of new positions due to growth in demand.

drawn, patterns of enrollments in higher education, choice of major, retention in the educational system, and career directions following receipt of the degree. Perceptions of economic and occupational demand also have an effect.* Long-term projections of possible changes are of particular import for physics, where the training pipeline frequently requires over 10 years. The physics Ph.D.s of the middle-1990's are formulating their initial career decisions now. We will first present short-range projections for the production of Ph.D. physicists and then venture into the relatively uncharted territory represented by the remainder of the 20th century.

Physics Ph.D. Production. Most of the new physics Ph.D.s of the late 1980's are already in the graduate school pipeline. Extrapolating from first-year graduate students at Ph.D.-granting departments, a best past-production predictor, we expect 6800 physics Ph.D.s to be awarded between 1984 and 1990.† Note should be made of the projected increase in the foreign component, a reflection of the dramatic increase in first-year foreign graduate students since 1979 (Figure S2-7).

Projections of Ph.D. production through the remainder of the century involve analysis of the education pipeline leading to graduate school. The group of 18- to 24-year-old males, from which traditional undergraduate physics majors and subsequent bachelors are drawn, will have decreased by over 20% by 1996. However, because of the increasing emphasis on the utility of a scientific background in tomorrow's

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*See, for example, R. Freeman, The Labor-Market for College-Trained Manpower, Cambridge, MA, Harvard University Press, 1971, and R. Freeman, "Supply and Salary Adjustments to the Changing Science Manpower Market: Physics, 1948-1973." American Economic Review 65: 27-39, March 1975.

†Physics Ph.D. students complete their programs in 4-9 calendar years respectively at the following rates: 3%, 7.5%, 14%, 11%, 6%, and 1.3%. Thus, on the average, approximately 43% of the first-year students eventually earn their Ph.D.'s. The last two years of the short-term projections were supplemented by extrapolations of first-year graduate students from junior majors using linear regression analysis.

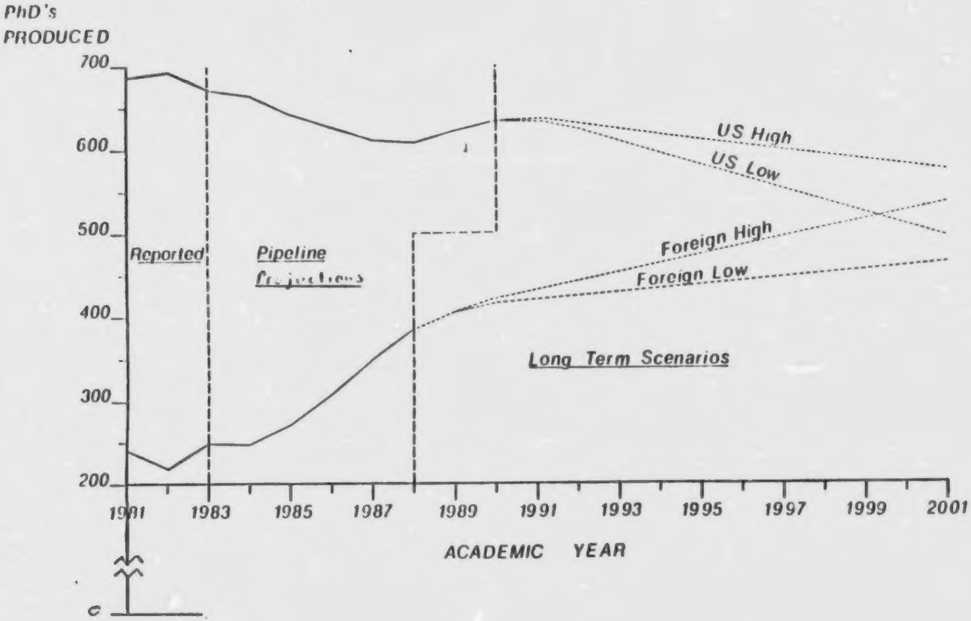


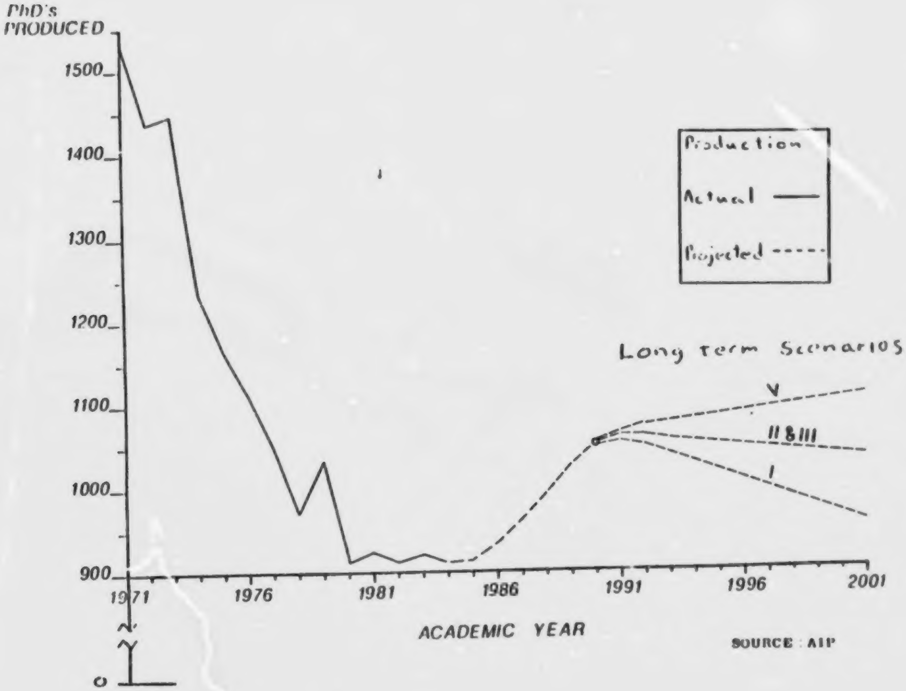
Figure S2-7. Physics Ph.D. Production by Citizenship, 1981-2001.

technological society, our probable scenario assumes a more modest decline in physics bachelors of 10% from current levels. This presupposes that steps will be taken to alleviate the deteriorating condition of precollege science education and that potential physics majors are, thus, not turned off from science in general before even entering college.

Approximately one-third of physics bachelor's recipients go on to physics graduate study. Another 15% of the first-year physics graduate students come from other disciplines. Our model assumes that the latter relationships will remain relatively stable in the future.

The participation of foreign graduate students, which has increased dramatically since 1979, will have an important influence on future Ph.D. production in physics. The scientific and technological needs of both developing and developed countries are expected to stay high during the remainder of the century. Our model thus assumes a growth in the number of foreign students of between 1 and 2-1/2% a year through 2001. The effect on Ph.D. production will depend on the graduate-school completion rate of these students. In the final years of the century, we project between 980 and 1100 total physics Ph.D.s a year (Figure S2-8). Under the most extreme scenarios, U.S. citizens around the end of the century may become a minority of the physics Ph.D. recipients.

Supply of Physics Ph.D.s: 1981-2001. Physics Ph.D. production does not equal supply. Two major factors which reduce this pool must be taken into account: immediate outmobility from physics, and the return migration of foreign degree recipients. Many physics Ph.D.s, traditionally about 20%, move into nonphysics employment within 3 years of their degree. This outmobility increased to 30% during the difficult employment market of the early and middle 1970's, and it has not shown any marked decrease since. The current high level, however, seems to be guided more by pull than by push factors. Our model assumes that this outmobility will move towards the more typical 20% level, as basic research opportunities in physics improve during the 1990's.



SOURCE : AIP

Figure S2-8. Physics Ph.D. Production, 1971-2001.

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The second factor affecting the supply of new physicists is the return home of new Ph.D.s who are foreign citizens. We estimate on the basis of past experience that one-half of these foreign nationals will return home, either immediately after receiving their degrees or following an ensuing postdoctoral or other temporary position. This phenomenon is sensitive to change. With the foreign component potentially approaching half of the Ph.D. production, such changes could have a major effect on the available supply. While U.S. citizen physics Ph.D.s are expected to decline, the supply of foreign Ph.D.s could double by 2001 (Table S2-7).

S2.6.3 The Demand-Supply Balance

Figure S2-9 illustrates the projected range for the supply of new physicists and the demand for Ph.D.s to work in physics. As discussed, forecasting either supply or demand involves many parameters, some unknowable. The shaded portions of the figure reflect our best estimates of the likely demand and supply levels during each of the four 5-year periods through the remainder of the century. We project a balance between likely demand and supply through 1991. Later in the 1990's, however, it appears that the supply of new physicists may not match the number of possible physics openings. If this mismatch occurs, increased competition among employers for well-trained physicists is likely.

The divergence between probable demand and supply may be even greater than we have indicated, because it does not include the projected increase in employment opportunities in the many neighboring scientific and engineering areas where physicists have always made contributions of major import.

S2.7 Conclusion

If the assumptions outlined in the previous pages hold over the remainder of the 20th century, we project a precarious balance between demand and supply through the early 1990's. Beyond that, there are likely to be more opportunities than new physicists to fill them. There

Table S2-7

Physics Ph.D. Production and Probable Supply by 5-yr Groupings, 1981-2001

Academic Years	Total Number of New Ph.D.s	Total Number of Foreign Ph.D.s[a]	Estimated Number Available to Labor Force[b]
Reported and Pipeline Projections			
1981-1986	4591	1296	2760-3150
1986-1991	5096	1985	2870-3280
Long-Term Scenarios[c]			
Low U.S. - Low Foreign			
1991-1996	5140	2170	2840-3250
1996-2001	4890	2280	2630-3000
Low U.S. - High Foreign			
1991-1996	5290	2320	2890-3310
1996-2001	5190	2580	2730-3120
High U.S. - Low Foreign			
1991-1996	5260	2170	2920-3340
1996-2001	5200	2280	2840-3250
High U.S. - High Foreign			
1991-1996	5400	2320	2970-3400
1996-2001	5500	2580	2950-3370

---

[a] It is assumed that half of the foreign citizens will return home within 4 years of receipt of their Ph.D.s.

[b] This column indicates the number of Ph.D.s available after return migration of foreign citizens and immediate outmobility from physics of new Ph.D. recipients. The ranges in the above estimated supply reflect the effect of immediate outmobility rates varying from 20 to 30%.

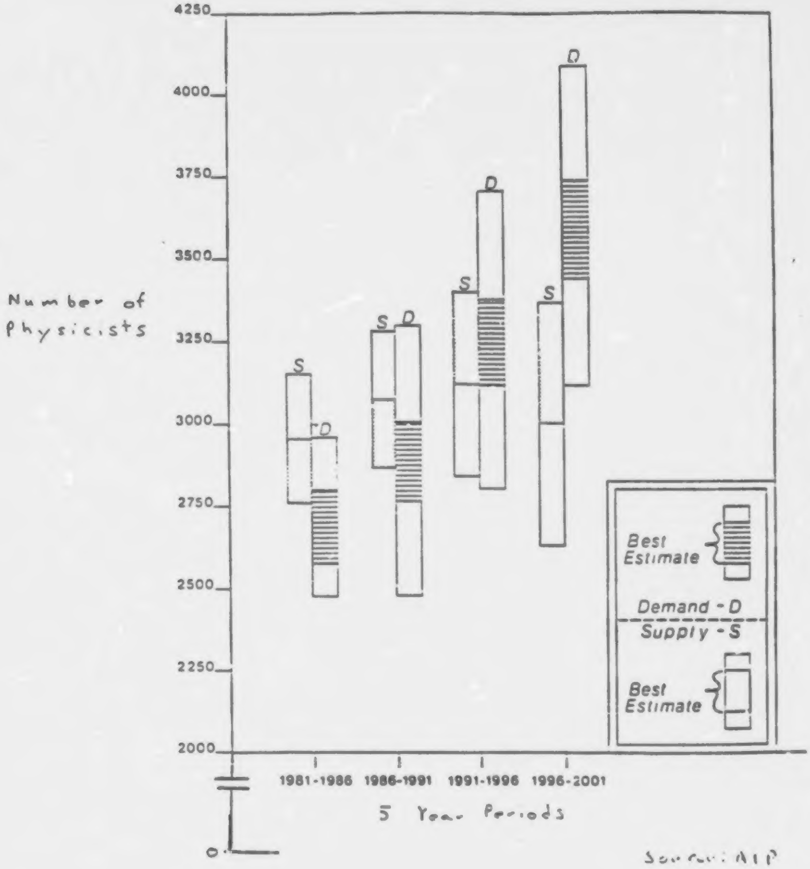
[c] The long-term scenarios indicate Ph.D. production under the following probable range of changes in 1st-year graduate student enrollment in physics programs:

Low U.S.--1st-year physics graduate students who are U.S. citizens are assumed to decline by 22% between 1985 and 1997. This would closely track a projected 25% decline in the number of total BA's received by 22-year-old males, the traditional source of physics graduate students.

High U.S.--1st-year physics graduate students who are U.S. citizens are assumed to decline by 10% between 1985 and 1997. This would result if physics were to attract significantly more than current levels of the traditional pool of 22-year-old male BA's.

Low Foreign--1st-year physics graduate students who are foreign citizens are assumed to increase by 1% per year over current levels between 1985 and 1997.

High Foreign--1st-year physics graduate students who are foreign citizens are assumed to increase by 2-1/2% per year over current levels between 1985 and 1997.



Source: AIP

Figure S2-9. Projected Demand for and Supply of Physicists by 5-Year Period, 1981-2001.

will be keen competition among disciplines for the brightest students and among employers for new Ph.D.s. Under each of our scenarios, the physics labor force is seen as becoming increasingly dependent on non-U.S. citizens. With such a large leverage, any changes in the retention of the foreign component could have a strong effect on the overall demand and supply picture.

The rest of the century represents a rather broad span of time. The activities of the physics community, the Federal Government, and industry could certainly help to alleviate any pending shortages. The excitement inherent in physics and the opportunities for further research are great. It would be unfortunate if an insufficient supply of qualified physicists constricted these opportunities. Now is the time for the physics community to seriously consider means for attracting the bright students of tomorrow. In this effort, we must recognize that the largest untapped pool of potential new physicists can be found among those groups underrepresented in the past.

APPENDIX 2

American Engineering Association

P.O. BOX 18473 Ft. Worth, Texas 76118

July 16, 1985

Hon. Don Fuqua
ATTN: MR. RADFORD BYERLY
2321 Rayburn Building
Washington, D.C. 20515

Dear Representative Fuqua:

This letter is to extend and amend my remarks as presented to the Government & Science Task Force of the Committee on Science and Technology on July 9, 1985 concerning supply/demand of engineers.

In any discussion of a shortage of engineers, there are two criteria which must be addressed before we can declare a shortage.

They are: what are we short of and at what salary level are we short of these individuals? I.e. are we short of the generic engineer or are we short of "Electrical Engineer/Project Manager" as described in the enclosed advertisement (Courtesy of the Committee of Concerned EE's - P.O. Box 19, Massapequa, N.Y. 11762).

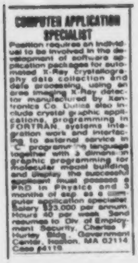
For the record, the ad states "High energy cosmic rays, including design, maintenance and development of electronic systems and controllers. Requires MS or ME degree in Electrical Engineering and knowledge or experience in basic cosmic ray physics, designing and drafting of printed circuits and realtime programming on the PDP-11 computer using FORTRAN with the RSX-11M operating system." SALARY LEVEL 21,000 DOLLARS PER YEAR.

This ad appeared in EDN January 26, 1984 and is a job which already has an alien engineer occupying it. Applicants were to reply to the Utah Job Service at 1234 South Main Street, Salt Lake City, Utah, 84137 - Job Order #28940. While I have not talked to the Utah Job Service, I am certain that they received no applications from U.S. citizens for that job.

If we are talking of the generic engineer as being in short supply, there is absolutely no shortage. If we are talking about the latter, the alien who occupies that position is probably the only person in the world who is qualified as described. As you can see the ad was written so very narrow as to exclude nearly everyone except the alien.

The other factor involved is that of salary. We MUST define at what salary level we are short of these disciplines. Certainly there is a shortage of the Electrical Engineers with the qualifications required in the ad who will work for $21,000. If that position paid $40,000 per year, there would be many more applicants.

I question our ability to declare a "true" shortage of anything more restrictive than the curriculum our colleges and universities graduates. I guarantee that there is no college in the country that offers a single degree which would qualify a person for the position in the ad above. I should also point out that this ad is not an isolated abuse, it is quite common.

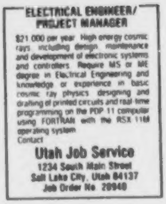


COMPUTER APPLICATION SPECIALIST

Position requires an individual to be involved in the development of software application packages for automated X-Ray Crystallography data collection and data processing, using an area imaging X-Ray detector manufactured by Xentronics Co. Duties also include crystal graphic applications, programming in FORTRAN, systems integration work and interfacing to external service in "C" programming language together with 3 dimension graphic programming for molecular model building and display. the successful applicant must possess a PhD in Physics and 3 months of exp. as a computer application specialist. Salary $23,000 per annum. Hours 40 per week. Send resumes to Div. of Employment Security, Charles F. Hurley Bldg., Government Center, Boston, MA 02114 Case #4119

Boston Globe
2/7/84

PH.D. (PHYSICS)
($23,000/yr.)



ELECTRICAL ENGINEER/ PROJECT MANAGER

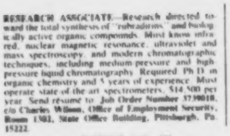
$21,000 per year. High energy cosmic rays, including design, maintenance and development of electronic systems and controllers. Require MS or ME degree in Electrical Engineering and knowledge or experience in basic cosmic ray physics, designing and drafting of printed circuits and real-time programming on the PDP 11 computer using FORTRAN with the RSX 11M operating system.
Contact

Utah Job Service
1234 South Main Street
Salt Lake City, Utah 84137
Job Order No. 20940

EDN JANUARY 26, 1984

286

MSEE
($21,000/yr.)



RESEARCH ASSOCIATE—Research directed toward the total synthesis of "rubradirins" and biologically active organic compounds. Must know infrared, nuclear magnetic resonance, ultraviolet and mass spectroscopy, and modern chromatographic techniques, including medium-pressure and high-pressure liquid chromatography. Required Ph.D. in organic chemistry and 5 years of experience. Must operate state-of-the-art spectrometers. $14,500 per year. Send résumé to: **Job Order Number 3730018, c/o Charles Wilson, Office of Employment Security, Room 1302, State Office Building, Pittsburgh, Pa. 15222.**

520 SCIENCE, VOL. 223

3 FEBRUARY 1984

PH.D. (CHEMISTRY)
($14,500/yr.)

By this time, we hope all readers are shrewd enough to understand that the ultimate employers are not the various state employment offices. An alien who graduates from an American college must find a job to remain here. Since the job, and not the salary, is all-important, unethical employers take advantage of the situation. Before an alien may be hired, the employer must show that no American could be found to fill the opening. The employer underwrites the cost of an ad, placed over the name of the state employment office. When, as expected, no American applies for the low-paying job, the employer is then free to offer the job to the alien - the intent all along.

But the law states that the advertisement must offer the "going wage" for that position. Too often, the state employment office does not conduct the required Area Salary (or Economic) Survey and, instead, relies for the salary on the very employer in whose behalf the ad is placed!!

The blame for this rests with the U.S. Department of Labor's Employment and Training Administration, 601 D Street NW, Washington, DC 20213. And the person who is supposed to administer the alien certification programs in the various states is Mr. Emery Biro, 202/376-6850. He is doing a lousy job and he is not competent. If you call him, be sure to mention your affiliation with the Committee of Concerned EEs.

COMMITTEE OF CONCERNED E.E.s
P.O. Box 19
Massapequa Park, N.Y. 11762

BELLMORE N.Y. FEB 27 '84
U.S. POSTAGE 20

FIRST CLASS MAIL

Bill Reed
1708 Westover Dr
Arlington, TX 76015

American Engineering Association

P.O. BOX 18473 Ft. Worth, Texas 76118

Hon. Don Fuqua, Chairman
Committee on Science & Technology
2321 Rayburn Building
Washington, D.C. 20515

August 7, 1985

Dear Representative Fuqua:

When I testified before the Government & Science Task Force of the Committee on Science & Technology on July 9, 1985, it was indicated that could present written testimony on the subject of foreign students and their impact on education and the engineering profession.

Enclosed are the views of the American Engineering Association on the subject of foreign students, which I hope will be included in the record of the hearings.

We appreciate the opportunity to make our views known to the Task Force and the Committee.

If you have any questions or want further information, please ask. I can provide supporting documentation if desired.

Thank you for soliciting views other than those of industry and academia. I hope the information we present is refreshing and useful.

If I can be of any help in the future, please let me know.

Billy E. Reed

Billy E. Reed, President
American Engineering Association

RECEIVED
AUG 1 3 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

TESTIMONY
of
THE AMERICAN ENGINEERING ASSOCIATION

as presented to

GOVERNMENT & SCIENCE TASK FORCE

of

THE COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES

HEARINGS ON FOREIGN STUDENTS

AUGUST, 1985

by

BILLY E. REED, PRESIDENT

PREFACE

The reader should keep in mind that this presentation has been written from the perspective of the American working engineer and discusses the benefits and drawbacks as seen by a taxpayer and a member of the engineering profession.

This outlook is, however, very important as the overwhelming majority of all written discussions of foreign students centers on the technical or scientific professions. Seldom if ever do you see an article on a foreign student who majors in history.

FOREIGN EXCHANGE PROGRAM

The concept of the exchange of students between countries was based on two basic principles. One would provide a cultural exchange between countries and therefore nurture better understanding between nations. If we could only understand each others culture a little better, we would have a better chance at world peace.

The second principle would have students from less fortunate countries study here to gain the educational tools needed to help elevate their countries to self-sufficiency.

Both of these principles are valid only if those students studying here return to their homelands after graduation. **TO STAY HERE DEFEATS THE ENTIRE CONCEPT THE PROGRAM WAS BASED ON.**

GROWTH

In the twenty-nine years between 1955 and 1984, the population of foreign students has experienced a nearly 1000% growth, starting with 34,232 in 1955 to 338,894 in the 1983/1984 school year. This percentage of growth has taken place much faster than the growth of all students in our colleges and universities. The U.S. 1983/1984 total is approximately one third of ALL STUDENTS, WORLDWIDE, WHO STUDY IN A COUNTRY OTHER THAN THEIR NATIVE LAND. While the total number of students nearly doubled in our colleges and universities between 1965 and 1975 due to the World War II baby boom, it peaked in 1982 and has since decreased and remained fairly flat.

The growth of foreign students has reached a plateau, although each year brings a "new record" enrollment. This plateau is apparently due, in large part, to the declining number of Iranian students after the hostage crisis. The number of Iranian students peaked in the 1979/1980 school year at 51,310 and had declined to 20,360 for the 1983/1984 school year.

While there are few if any studies which focus' on the reasons for the huge increases in foreign student enrollment, I would like to offer an educated opinions on this facet of the situation.

First and foremost in the list of reasons for this phenomenal growth is the ease with which student visas may be adjusted to "permanent residence status", even though the definition of a student contains the phrase "resident of a country which he has no intention of abandoning". This one reason alone probably carries more weight than all of the other reasons combined.

In spite of the "problems" with our educational system, we still offer the best education in the world. Most foreign students could afford to attend school anywhere, but still chooses the United States.

This is one of the few countries in the world where a foreign student can work and go to school at the same time. Despite regulations to the contrary, all it takes for a foreign student to work is permission of the school, permission of INS (a rubber stamp approval) and a job offer.

When considering overall technology, the United States is the unquestioned technological leader of the world. Free exposure to U.S. technology is a great drawing card.

AREAS OF CONCENTRATION

Foreign students participate in virtually every field of study offered by U.S. universities and colleges, but the vast majority study in a very limited number of fields.

Over half of all foreign students (54.7%) study in only five areas. They are Engineering 23.1%, Business 17.9%, Physical Sciences 7.3% and Mathematics & Computer Science 6.4%. Four of these five fields were the exact fields "exempted" by the Simpson-Mazzoli immigration bill from the "return home" provision. The fifth field, Business, was not one of the "exempted" fields of Simpson-Mazzoli, but it is very easy for companies to acquire L1 visas for this category.

The fields one would expect to be the most helpful to a developing nation; agriculture, health sciences and education totaled only 11.5% of the foreign students enrolled in the U.S.. The breakdown is as follows: agriculture 2.8%, health sciences 4.1% and education 4.6%. Clearly, the intent of most foreign students is not to return home and help his nation, but to remain here.

BRAIN DRAIN

Earlier this year various newspapers across the country were reporting on the complaints of Taiwanese officials concerning the brain drain from Taiwan to the United States. Typical of the articles is one from the Los Angeles Times of January 31, 1985.

This article indicates that between 1951 and 1981, Taiwan had sent 67,000 students to the United States to study and less than 9,000 had returned. While there are few statistics in this area of foreign student demigraphics, I rather suspect that this case is much closer to the rule than the exception.

A few years ago, many third world countries had banded together in the United Nations seeking some 47 Billion dollars in damages from the United States to help repay for the trained scientist and engineers that we had allowed to remain here.

Complaints have been received from the South Korean government on this issue also. South Korea and other countries have programs to "lure" their U.S. educated scientists and engineers back.

The United States has, in effect, entered into an agreement by accepting foreign students to study here with the provision they return home. We should see that we live up to the terms of that agreement.

IMPACT ON U.S. EDUCATION

Other than exposure of our children to diverse points of view and cultures, the foreign student has few positive effects on our educational system.

In the February, March and April time frame of 1983, academia was before Congress seeking funds to enlarge our schools of engineering, science, mathematics and computer science to produce more technically trained workers in order to "maintain our technological superiority". Thousands of articles decried the shortage of engineers in newspapers and trade journals across the land.

We were "short of not only engineers but teachers to train the engineers" we were told. Many articles spoke of our colleges and universities having to turn away many qualified applicants (up to one third) for a lack of room and a lack of qualified teachers. The teacher "shortage" seemed to have peaked at about a ten percent shortfall. This shortage was reaching a "crisis level" according to many of the "experts". The only response to the "crisis" level shortages was to enlarge the schools to train more engineers and scientists.

Congress reacted to this blitz as one would expect. They appropriated billions of dollars of taxpayer money to fund the universities to try to cope with this crisis. Industry rushed to meet this crisis with a tax deductable generosity of unparalleled dimensions.

Somehow in the rush to save the nation from technical obsolescence, industry and academia failed to point out a few very crucial facts. Perhaps the most telling was that many of our top universities were **OVERSEAS RECRUITING STUDENTS** to fill these newly enlarged schools. Of course the fields of study they were "selling" overseas were engineering, science, mathematics and computer science. Their justification for this action was that the population of college age youth in the United States was declining since the peak of the world war two "baby boom" had passed.

If the "crisis" shortage stories were real, academia was filling our precious spaces in the schools with foreign students, which "we all know must return to their native lands upon graduation" and would therefore not be available to solve our crisis. If the stories were not real, then academia has perpetrated one the largest frauds in the nations history on Congress and the public.

With over twenty three percent of all engineering students, citizens of another country, and a faculty shortage of between eight and ten percent, it never occurred to any one that we could solve both the problem of more space and faculty by reducing the number of foreign students allowed to study here.

This would not necessarily translate into fewer engineers. It would have opened up the schools to accept more citizens in engineering school and given the universities more time to prepare U.S. citizens for teaching. Professors from lesser demand fields such as physics could have been used to teach the lower level undergraduate courses in engineering. It doesn't take an engineering professor to teach first year chemistry or mathematics.

IMPACT ON EMPLOYMENT

The U.S. employment market is adversely affected in many ways by the employment of foreign students. For example, unemployment in the college age black and Hispanic youth is far above the national average. In Texas it is in the 35 percent plus range. I doubt that it is much different throughout the country.

Each foreign student that works while in school directly takes a job that could otherwise go to an unemployed minority. I do not know how many of the unemployed minorities could go to college if they were able to work while attending. I suspect that it is many.

AMERICAN YOUTH. UNDERPRIVILEGED YOUTH.

Many co-op programs would have more jobs if those jobs were reserved for our own youth. Employment means money and money means opportunity. The summer jobs program for unemployed youth in Washington, D.C. is a good example of the success and participation that this type of program can expect from our unemployed youth. This effort is deterred however when we have very high percentage of foreign students in the labor market.

When a foreign student graduates, he is given the opportunity of working for one year in his field of study under the "practical training" provision of the student visa. This must have a deleterious effect on that years graduating class' opportunity to gain employment.

This provision is legally useable only if the country of origin of the student has no industry to support a job in the students chosen field. This certainly raises the question of why we are training a non-citizen for a field in which there is little or no hope of gaining employment in is home country. Again, the student visa states that he must be a resident of a foreign country which he has no intention of abandoning.

Once the student graduates, if he is an engineering or technical graduate, he is immediately eligible for an H-1 non-immigrant visa as a person "of distinguished merit and ability". As an H-1 visa holder the alien may legally be hired regardless of the salary he is willing to accept or the number of American citizens seeking the exact same job. The only "distinguishing" feature of the foreign student at this point in his career is that he is normally willing to accept lower salaries to remain here.

A recent salary survey by one of the trade journals indicated that the non-citizen engineer averaged approximately eight percent less than his citizen counterpart. The differential is probably greater than that at the entry level.

FOREIGN FACULTY PROBLEMS

Everyone agrees that one of the reasons for a dearth of citizen graduate students and an excess of foreign graduate students in engineering is the low starting salaries of the academicians relative to industry.

Exactly the same forces that drives the industry marketplace also drives the academic marketplace. One of the reasons for the low salaries in academia is the willingness of the foreign graduate to work in that atmosphere for less than a reasonable wage. I have seen many "research assistant" ads with salaries for a Phd. in engineering for less than $20,000 per year.

He is willing to work here for less for several reasons: First is the attraction of permanent residency. An assistant engineering professor is the easiest way to the green card there is now. As in private industry this is the primary force in accepting lower salaries.

The second great incentive is the research facilities and the atmosphere within those facilities. While old and in need of renovation in some cases, they are still on the whole the best in the world. This is the second greatest magnet to the foreign graduate.

This marriage of the great "need" for more engineering professors and the willingness of the foreign graduate to remain here at lower salaries to fill that need in and of itself creates the second problem in engineering education.

I have been told by university officials that in Texas nearly ninety percent of the research assistants and assistant professors are foreign born. I doubt that it is much different anywhere in the country.

This problem is the one of communication between the teacher and the student. There has been many recent articles and instances of the American student who had to drop classes or fail courses because of the language barrier between the teacher and the student. Certainly if there is anywhere that communication is important it is in school. The quality of the engineering graduate and therefore the future of American technology is at stake.

The classic case of this type is at the University of Pittsbugh where the school refunded many students their tuition for classes taught by unintelligible instructors. It's nice they were able to get the refund, but who is going to refund the wasted time?

EXCLUDED CITIZENS

Those turned away from our schools of science and engineering were, of course, our nations underprivileged and minorities. During the early 1980's the ratio of foreign students to minorities at MIT was nearly one hundred to one. It was perhaps smaller than that at many other of our nations leading universities but it was still a national disgrace. There are currently roughly as many foreign students enrolled in our schools of engineering and science as there are U.S. minorities.

In testimony before the House Science Policy Task Force Dr. Clarence VerSteeg, Dean of the Northwestern graduate school described the efforts to attract more minority engineers and scientist as "scandalous". He went on to say "We have not done nearly enough to help them prepare for science and technology careers and then help them when they get there. NO ONE CAN TAKE MUCH PRIDE IN WHAT HAS BEEN DONE."

In the same hearings Mr. Alan Fletcher, executive director of the Office of Scientific and Engineering Personnel at the National Research Council stated there were no "compelling reasons" to expand the interest of social and ethnic minorities in careers in engineering and the sciences. He stated that despite an expanding base of potential students, the enrollment of these students continued to decline.

COSTS

The costs of foreign students are very difficult to estimate. There are many items to consider and little in the way of "hard" data on which to base these estimates.

We do know, for example, that in most states, foreign students pay tuition at the same rate as an "out of state" citizen. Generally this will cover between one third and two thirds of the actual "cost to educate" an individual when considering tuition only. I have seen estimates in the area of one billion dollars per year in tuition alone that must be picked up by the American taxpayer.

These costs must be weighed against the boost in the local economy brought about by the living expenses incurred by the foreign student.

Additional cost such as Immigration, Labor and State Department activities must also be considered as part of that cost.

While the vast majority of foreign students are law abiding and honest, there are hundreds of cases each year of foreign students involved in illegal activities. A few of the violations that we have documented includes fraud, drug trafficking, arms smuggling and murder. Certainly the costs of investigation, trial and incarceration must be considered.

TRANSFER OF TECHNOLOGY

Recent concerns over the transfer of technology to communist or otherwise unfriendly countries has totally overlooked, perhaps, the most obvious of the sources for that transfer, the foreign student. You can bet our enemies hasn't.

A list of so called "Designated Countries" (formerly called the "Communist Block" countries) is provided as part of the paperwork to be filled out when an individual applies for a security clearance. These countries are so hostile to the United States that the holder of a security clearance is required to **REPORT ANY CONTACT** with persons from any of those countries.

Over **TEN PERCENT OF ALL FOREIGN STUDENTS, STUDYING IN THIS COUNTRY, WERE FROM THE DESIGNATED COUNTRIES AND HALF OF THOSE WERE STUDYING ENGINEERING, SCIENCE, MATHEMATICS** or **COMPUTER SCIENCE.** In raw numbers it appears that of the 326,299 foreign students enrolled in U.S. schools for the 1981/1982 school year, there were 34,174 students from the "Designated Countries".

While 38.5% of all foreign students study one of these fields, the percentage gets much higher when we look only at the "Designated Countries". 49.35 percent of ALL students from the "Designated Countries" study these fields. Put another way, **OVER 22% OF ALL FOREIGN ENGINEERING AND SCIENCE STUDENTS ARE FROM COUNTRIES ON THE DESIGNATED COUNTRIES LIST.**

Our colleges and universities extensively use foreign graduates for research assistants. Much of this nations "sensitive technology" is developed within our institutions of higher education. **MUCH OF THIS TECHNOLOGY IS NOT CLASSIFIED DURING THE RESEARCH PHASE OF THE DEVELOPMENT CYCLE.** Only after a technology shows military importance is much of the research material classified.

NOTE: Statistics from Institute of International Education unless otherwise noted.

FOREIGN STUDENTS FROM DESIGNATED COUNTRIES
FOR 1981/1982

COUNTRY OF ORIGIN	TOTAL STUDENTS	ENG. STUDENTS	COMPUTER SCI.	MATHEMATICS	PHYS SCI.	% TOTAL
AFGHANISTAN	151	25	6	2	6	25.83%
ALBANIA	5	0	1	1	0	40.00%
ANGOLA	22	10	1		0	50.00%
BULGARIA	4	1	0	0	0	25.00%
COMMUNIST KOREA	104	12	4	2	6	23.08%
CUBA	1583	153	83	7	18	16.49%
CZECHOSLOVAKIA	40	5	0	1	2	20.00%
ESTONIA - NO DATA						
ETHIOPIA	932	105	57	25	38	24.14%
GERMAN DEMOCRATIC REPUBLIC	17	0	1	1	3	29.41%
HUNGARY	30	1	5	2	1	30.00%
IRAN	21173	9236	1009	648	939	55.88%
IRAQ	899	280	21	28	53	42.49%
KAMPUCHEA - NO DATA						
KURILE ISLANDS - NO DATA						
LAOS	438	30	8	4	1	9.82%
LATVIA - NO DATA						
LITHUANIA - NO DATA						
LYBIA	1835	821	89	51	130	59.46%
OUTER MONGOLIA	1	0			0	0.00%
NICARAGUA	673	114	29	4	12	23.63%
PEOPLES REPUBLIC OF CHINA	2763	534	227	142	325	44.44%
POLAND	324	48	4	17	30	30.56%
RUMANIA	45	9	2	2	0	28.89%
SOUTH SAKHALIN - NO DATA						
SOUTH YEMEN	23	9	1	0	0	43.48%
SYRIA	645	318	19	10	9	55.19%
TIBET	2	0	0	0	0	0.00%
U.S.S.R.	178	15	12	4	4	19.66%
VIETNAM	2064	704	141	59	38	45.64%
YUGOSLAVIA	223	38	12	15	25	40.36%
TOTALS	34174	12468	1732	1025	1640	49.35%

TERRORISTS

Our vulnerability to terrorism from inside the country is extremely difficult, if not impossible to assess. I do not think anyone is so naive as to believe that it is not just a matter of time before we start seeing terrorist activities within the borders of the United States.

The recent activities of the Shiite and Sikh terrorists should give this nation an idea of what could be in store within our borders if we fail to take at least the minimum precautions. The Shiites, in particular, are spread throughout many countries and seem to be gaining in strength. We were very lucky in the recent hostage crisis involving the TWA airliner.

Some of the easiest visas to get for entry into the United States are the F-1, F-2 and J-1 visas, those reserved for foreign students and their immediate family. Seldom does the State Department give a student visa applicant more than a cursory look before approving the visa.

Are we to wait for a terrorist attack within our borders before we consider not allowing those people with high probability of terrorist activities into the country? I think that would be a dreadful mistake.

We must remember that potential terrorists, upon graduation, rapidly become dispersed within our society and generally have total freedom of movement within the labor marketplace.

APPENDIX 3

TOMORROW

THE REPORT OF THE TASK FORCE FOR THE STUDY OF CHEMISTRY EDUCATION IN THE UNITED STATES

October 1984

American Chemical Society
1155 Sixteenth Street, N.W.
Washington, D.C. 20036

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EXECUTIVE SUMMARY

The American Chemical Society Chemistry Education Task Force finds that:

Misunderstanding of science is widespread and the public understanding of chemistry is poor.

Too little science is taught in the elementary schools, possibly because too few teachers are well qualified to teach it. Neither programs to assist improvement of teacher qualifications nor good teaching materials are readily available.

Too few teachers of chemistry in high schools are well grounded in the subject; those that are are spread too thin, have too few mechanisms available for maintaining and improving their qualifications, and are too easily wooed away to more satisfying and more remunerative employment.

Laboratory exercises are slowly disappearing from general chemistry education in both high schools and colleges.

College chemistry for nonmajors has yet to find an appropriate character; that for majors is beset with unanswered questions about curriculum content, especially as it relates to future professional employment.

Applications of both information technology and discoveries about learning are occurring haphazardly.

Demand for—and supply of—well-educated chemists are poorly related to each other. Arbitrary barriers to entry and progress in the profession continue to be reported.

Industry does much to aid science education, but should do much more.

The highest priority recommendations of the Task Force are:

To the United States Government:

- Vigorous and large expansion of National Science Foundation and other Federal programs to upgrade the quality of science instruction through direct service to teachers.
- Establishment of Federally supported Regional Science Centers as focal points for improvement of precollege science education.

To State agencies and curriculum bodies:

- Raising of teacher certification standards in science and mathematics, in both elementary and secondary schools.
- Increase in the amount and level of science and mathematics taught to all students.
- Improvements of teacher compensation and in conditions of employment.

To Scientific Societies:

- Formation of a National Council on Education in Science and Technology to coordinate and oversee national educational efforts, with emphasis on public understanding of science and on precollege education.

To the Chemical Industry:

- Strengthening and expansion of activities that bring the resources of the chemical industry to bear on improvement and support of science education at all levels.

To the American Chemical Society:

- Creation of a 5-year plan to improve chemistry education nationwide in the high schools.
- Consideration of how best to characterize opportunities in chemistry and the expectations of employers, identify necessary curriculum and resource elements, and utilize results of research to improve chemistry education.
- Expansion of efforts to provide information on chemistry and chemical affairs to Congressional and administrative decision-makers.

Grouped according to target entity, the principal recommendations of the Task Force are:

(N) With regard to National Concerns:

- Formation of a National Council on Education in Science and Technology to coordinate and oversee national educational efforts.
- Formation of a sub-Council on Public Understanding of Science and Technology.
- Formation of a sub-Council on Precollege Education in Science and Technology.
- Strong ACS participation in these efforts.

(A) With regard to All Levels of Education:

- Vigorous and large expansion of National Science Foundation and other Federal programs to upgrade the quality of science instruction through direct service to teachers.
- Expansion of Federal support of research and development in the use of computers and other information technologies in science education.
- Expansion of Federal support of research in science education.

(E) With regard to Elementary School Science:

- Coordinated effort by scientific and engineering societies to address the major problems of science education in the elementary schools.
- An immediate national effort by scientific and engineering societies to add science to the present basic triad of school subjects.
- Development of model science programs for each grade level K-8.
- Development of guidelines for certification of elementary school teachers to teach science.
- Establishment of Federally-supported Regional Science Centers as focal points for improvement of precollege science education.
- Expansion of ACS activities in the area of pre-high school chemistry education.

(H) With regard to High School Chemistry and Science:

- Creation of an ACS 5-year plan to improve chemistry education nationwide in the high schools.
- A national effort to raise teacher certification standards in science and mathematics and to secure adherence to such standards.
- Adoption of a national minimum standard that 3 years of science taught with laboratory and 3 years of mathematics be required for graduation from high school.
- Study of changes necessary to improve the high school chemistry curriculum.
- Adoption of a guideline that at least 30 percent of class time be devoted to laboratory exercises in the high school chemistry curriculum.

(T) With regard to Two-Year College Chemistry and Chemical Technology:

- Revision of the ACS 1970 "Guidelines for Chemistry in the Two-Year Colleges."
- Development by ACS of an outreach and consultation program to assist improvement of chemistry programs in two-year colleges.
- Establishment of an ACS approval service for Chemical Technology programs.
- Development of an ACS approval service for college transfer and other two-year college chemistry programs.

(B) With regard to University and College Chemistry and Science:

- National effort to attain acceptance of a requirement for admission to colleges and universities of at least 3 years of laboratory science and 3 years of mathematics taken in grades 9–12.
- National effort to assure that the laboratory science requirement for any baccalaureate degree is at least 10 percent of the undergraduate credit that must be earned by the student.
- Establishment of guidelines to the appropriate balance in college-level chemistry courses for nonscience majors among the fundamental principles of chemistry, applications of chemistry, and the place and role of the chemical sciences in contemporary society.
- Development of a program of workshops and other activities to increase interaction among teachers of the natural sciences and engineering, the arts, humanities, and the social sciences.
- Adoption of a standard that all college-level foundational chemistry courses, whatever their student clientele, include substantial and significant laboratory work.
- Preparation by the ACS Committee on Professional Training of recommendations concerning the content of chemistry courses intended for students who are not majors in chemistry.
- Development by ACS of curriculum modules in such aspects of chemistry as are germane to the curricula of professional schools of law, business, and the health professions, among others.
- Inclusion in the budgets of instrument purchase programs of additional funds to permit development of cooperative mechanisms for the maintenance and repair of such equipment.
- Sponsorship by the ACS of the preparation of position papers providing advice and guidance to faculty members on ways to include or improve instruction in the undergraduate curriculum on a number of specific topics and areas.
- ACS consideration of how best to characterize opportunities in chemistry and the expectations of employers, identify necessary curriculum and resource elements, and utilize results of research to improve chemistry education.
- Consideration of the mission of the ACS Committee on Professional Training.
- ACS leadership of efforts to modernize the concept and structure of technical libraries.

(C) With regard to Careers in Chemistry:

- Government and industrial support of a program of postdoctoral appointments for research on problems of national concern to assist bridging temporary differences in employment demand and scientist supply.
- ACS sponsorship of efforts to identify and correct arbitrary restraints on women, minorities, and other special segments preparing for or practicing the profession of chemistry.
- Increased development, testing, and evaluation of electro-optical systems for continuing education; expansion of ACS continuing education services.

(D) With regard to Industry and Education

- Strengthening and expansion of activities that bring the resources of the chemical industry to bear on improvement and support of science education at all levels.
- Establishment of an ACS staff Office to deal with activities at the academic-industrial interface.

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PREFACE

The American Chemical Society Chemistry Education Task Force was appointed in January 1983 by the then-Chair of the Society Committee on Education, Dr. Stanley Kirschner, and began work almost immediately.

The charge to the Task Force was a simple one: *Examine the state of chemistry education in the United States today and make such recommendations for action as seem appropriate in light of the findings.* We determined to look at all levels of education and at both formal and informal modes; we did not feel that we were directed to be practical or even reasonable.

While the funding of the Task Force's work was generous, it was not lavish. It was realized early that surveys over the various parts of the national educational apparatus, of students and other consumer groups, and even of the smaller collection of persons who have thought and are thinking deeply and conscientiously about education in the sciences, were not possible. Rather, the Task Force decided to use as leverage for its experience and as the starting point for its thinking the substantial and growing collection of reports published recently (some of the most important being issued during the active work period of the Task Force) by several bodies national in scope, by a myriad of groups more limited in compass, and by informed and concerned individuals.

Among the first are the reports of The National Commission on Excellence in Education (April 1983) and The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, and many reports of conferences and other studies of problems in chemistry education done under the auspices of the American Chemical Society. Complete listings of these source materials will be found in the Bibliography.

Members of the Task Force made no secret of their work and information flowed freely to us. As the program of working meetings was followed, a number of invitations were extended to interested persons to provide opinion, expressions of concern, proposals for the solution of perceived problems, etc. Later, when the recommendations of the Task Force were in preliminary form, several hundred persons were asked to comment on that part of the Task Force work product. Finally, drafts of this report were sent to a small number of very knowledgeable individuals for critical review.

The Task Force has identified some serious problems in science education and in chemistry education, and recommendations are made for action to improve such problem situations. Not all of the identifications or recommendations are entirely original with this Task Force—we are far from the only persons addressing these matters in a formal, organized fashion. Our debt to the efforts of other groups and individuals is substantial. Perhaps if the number, scope, and concern of such mutually indebted endeavors grows sufficiently, something will be done to allocate human, fiscal, and physical resources to the solution of the problems.

INTRODUCTION

Any study of the state of chemistry education must begin with a look at the whole of which chemistry education is a part.

Enrollment fluctuations notwithstanding, education in the United States is a huge enterprise. Currently, the elementary schools enroll 27 million students, high schools 14 million, and colleges and universities over 12 million. There are about 100 thousand precollege institutions and they employ 2.5 million teachers; the 3300 college-level institutions have 620 thousand faculty members. The leverage of such large numbers is enormous: if every high school student were given the opportunity to perform a precipitation test for aqueous chloride ion by using one milliliter of tenth molar silver nitrate solution, the reagent cost would be over $80,000.

The current budget of the U.S. Department of Education is about $14 billion; the aggregate of annual state, Federal, and municipal expenditures on education (much of it for instruction) has been estimated at $150 billion, about half as large as the budget of the Department of Defense. Average annual expenditures per pupil are about $2000 in the schools, over $3000 in two-year colleges, and over $9000 in four-year colleges and universities.

Science and mathematics education starts early in the elementary schools. For grades K-3, 17 minutes per day are devoted to science, 41 to mathematics, and 95 to reading; in grades 4–6, science gets 28 minutes per day, mathematics 51, and reading 66. Elementary school students maintain more positive attitudes toward mathematics than toward school in general, but there is a steady decline in such affection as the grade level increases; the trend is reversed for science. Forty-eight percent of nine-year olds identify mathematics as their favorite subject, 6 percent choose science; among seventeen-year olds, mathematics is the favorite subject of 18 percent, science of 12 percent. Unfortunately, student achievement in both science and mathematics has declined steadily at all age levels during the last 15 years.

Nationwide, there has been a steady decrease in the amount of science completed by students during the high school years. In the decade ending in 1981, students completing more than two years of science in grades 10–12 declined from 31 to 25 percent of high school seniors. The trend is similar among college-bound high school seniors, though they included more science in their programs than did other students; the median number of years of courses completed in grades 7–12 by the college-bound group was: 4.2 years of English, 3.7 of social sciences, 3.5 of mathematics, 1.3 of biological science, and 1.6 of physical sciences, in 1980–81.

In 1980–81, about 2.8 million students graduated from high schools and about 1.5 million of them went on to some higher education. Their potential may have been somewhat lower than that of the corresponding group of students seeking college admission in 1966–67: in those fourteen years, the average score on the Verbal part of the Scholastic Aptitude Test (SAT) declined from 467 to 425, on the Mathematics part from 494 to 468.

The division of the stream of students entering colleges and universities into employment interest groups, and therefore into majors or fields of concentration, occurs early, and there have been some marked changes in the last decade or so. In 1970, 19 percent of college freshmen indicated precollege teaching as a probable career (11 percent pointed toward the secondary schools) and 2.5 percent one of the physical sciences; by 1982 these indications became 5 percent (2 percent) and 2.8 percent, respectively. The average Verbal SAT scores of intended education majors fell from 418 to 391 in this period, that on the Mathematics part from 449 to 418. The corresponding figures for intended majors in a physical science changed more: average Verbal SAT fell from 515 to 438, average Mathematics SAT from 580 to 520.

Colleges and universities awarded (all fields) 420 thousand associate degrees in 1980–81, 940 thousand baccalaureates, 360 thousand masters, and 40 thousand doctorates. In education there were 108 thousand bachelor degrees awarded in 1980–81 (down from 194 thousand in 1972–73), 99 thousand masters (down from a historic high of 128 thousand in 1975–76), and 7 thousand doctorates (a rate essentially unchanged for over a decade). In physical science education, baccalaureate degrees fell from 900 in 1970–71 to 600 in 1980–81, masters from 800 to 500, and doctorates from 90 to 80; in mathematics education the decline was steeper: baccalaureate degrees fell from 2200 in 1970–71 to 800 in 1980–81, masters from 800 to 400, and doctorates from 50 to 30.

There have been declines in degree production in the physical sciences, including chemistry, in this period, but they have been much less—averaging about 10 percent at any level. In 1980–81 for example, there were some 10 thousand baccalaureate degrees awarded in chemistry, 1800 masters, and 1600 doctorates; the corresponding figures for all physical sciences were 21 thousand, 5.5 thousand, and 3600, respectively.

By 1980–81 the proportion of graduating certifiable teachers in mathematics who did not apply for school teaching positions had reached 27 percent; the figure for physical science certifiable teachers was higher. In 1980–81, of the individuals teaching primarily mathematics and/or science, 87 percent were certifiable in some field—but only 44 percent in the field in which they were teaching.

College and university chemistry faculty members are clearly undercompensated in comparison with their colleagues in industry, and the steady decline in student interest in rigorous fields has not helped their esprit. But their problems of image, morale, and compensation are trivial in comparison with those of teachers in the elementary and secondary schools.

Favorable attitudes toward their careers by teachers in schools decreased dramatically in both intensity and frequency of occurrence during the past two decades. Teacher morale appears to have been affected more adversely by factors such as changing public attitudes toward the schools and teachers, media treatment of the institutions and the profession, and student attitudes toward learning, than by concerns over inadequate teacher compensation. Even student behavior and class size are rated by teachers as less important cause agents for career-related dissatisfaction than the attitudes of others about the profession.

Not that there are not real problems of facilities and finance in the schools generally. Science teachers have greater need than others for special kinds of facilities and equipment, costly materials for instruction, smoothly functioning supply systems, and safe space. Seldom are these forthcoming in the quantity or quality needed.

Teachers feel real pressures born of student interest in science and the relentless change of the discipline. Only about a quarter of elementary school teachers are confident of their ability to teach what science there is in the curriculum at that level. A somewhat smaller proportion (but still over an eighth) of secondary school teachers of science admit to feeling inadequately qualified to teach one or more of their courses. The interest of high school science teachers in improving their qualifications is well evidenced by the fact that by 1977 forty-seven percent of them had attended one or more of the institutes sponsored by the National Science Foundation; unfortunately, attrition in the profession and the demise of that program have lowered this fraction substantially.

What is the state of chemistry education in the United States today? Chemistry as such is ordinarily a high school and college subject, though there is some chemistry content in the science taught in the elementary schools. Nearly everywhere one finds evidence of student, teacher, and parent interest in science as a school subject. In many places one finds that this interest can be demonstrated in terms of good teaching, sound student achievement, and strong parental and community support for the programs and facilities necessary if sound instruction is to be given. In many places one finds examples of dedication, commitment, and determination. But, those places are rather scattered. The fraction of the students at any grade level who learn in an environment as positive as that reflected above is quite small—too small for good service to the future of either the students or the Nation.

At too many places, at too many levels, teachers are ill-qualified to teach science. Elementary school teachers often have had no serious science instruction in their preparation for the profession. At the high school level, few who teach chemistry have real subject matter competence in the discipline, and those who do are increasingly easily wooed away to other professional employment. In both the high schools and in smaller colleges, too many faculty members are forced into an instructional pentathlon—spread thin over far too many different assignments for quality performance in any of them. There is very little organized help for teachers at any level who want to maintain or improve their competence to give instruction in a science discipline, chemistry included.

Curriculum materials of high quality and demonstrable effectiveness do not exist in profusion; the lower the grade level the greater the need. Marketing forces push instructional materials toward conformity and uniformity, with the predictable result that neither diversity nor excellence is found or served. The computer, instead of liberating instruction, threatens to put it into a straitjacket—conveying subtly, for example, the false notion that science is all known and closed instead of exploratory and open-ended. Laboratory exercises, in part because they are logistically difficult and have always been expensive, are being seen more and more often as unnecessary—students are expected to learn from watching someone else's "hands on" instead of their own.

Colleges and universities have similar problems. Chemistry is a neglected "liberal art"; neither admission nor graduation requirements reflect its place or value in contemporary life, or its intellectual worth. Pressures for efficiency drive curricula toward single approaches to chemistry in spite of the diversity of student interests and capacities. There is complaint that chemists isolate

themselves from meaningful interaction with their faculty peers in other fields, both science and nonscience, which depend on chemistry for service instruction. Many questions are raised about the content, currency, and relevance of the undergraduate preprofessional chemistry curriculum in regard to the career goals of individuals and the broad spectrum of employment opportunities afforded its graduates. Some assert that there is a serious mismatch between the legitimate expectations of those who employ chemists and the assumptions of those who devise and implement the curricula which prepare them for employment. In some areas, e.g. information science as applied to the practice of chemistry, industries report that they cannot rely on their new employees being adequately prepared. Poor funding of higher education is moving the cutting edge away from higher education toward industrial laboratories, which seem to be able to keep their instruments on line. Learning in chemistry must be lifelong, but continuing professional education is accorded much less attention than it deserves.

There are still other kinds of problems at the academic-industrial interface. Industry does much for education, but only a fraction of what would be desirable in its own long-term interest; this is especially true where the public understanding of science is concerned—with chemistry and industry a very sensitive area. Industries do little to exchange information about any good and effective programs that they have in education; and they do even less to communicate such tidings to the public. Industry also hears a different drummer than does the educational system that produces its scientists; as a result, industrial demand for chemists, for example, can change ten times as rapidly as the educational system and students can respond. And, in both industry and academe, women, minorities, and the handicapped continue to report artificial barriers to the progress of their careers.

The conclusions drawn from these findings by the Chemistry Education Task Force take the form of thirty-nine principal recommendations and numerous ancillary ones, all set forth in the sections which follow. We begin with recommendations (N) that reflect our concern for the nationwide low level of public understanding of science, and our conviction that the momentum generated by recent national studies of school education, in general, and of education in mathematics, science, and technology, in particular, must be maintained. There follow some proposals (A) that relate to education at all levels. These are, in turn, followed by clusters which deal with problems at the levels of the elementary schools (E), high schools (H), two-year colleges (T), and colleges and universities (U). Sections dealing with matters related to the careers of some chemists (C), including continuing education, and with the special opportunity we believe exists for the chemical industry (I), complete the Report.

At the start, the Task Force was advised to concentrate its attention on post-secondary chemistry education, with special emphases on the undergraduate and graduate preparation of chemical scientists and on their continuing professional education. Soon, however, many urged us to broaden the scope of the study, expressing the conviction that the education of nonscientists and critical problems in precollege education were equally deserving of our efforts—that the whole of chemistry education should be looked at. We took the latter advice.

The recommendations of the Task Force reflect disquiet with precollege education in many respects, not just with instruction in chemistry or in science. Our disquiet is somewhat closer to alarm than our prose may suggest. The quantity of precollege education is great, but too often its quality is not. Much of the time we expect the wrong things of our system of education and employ poor tactics that evolve into worse strategy: to avoid discrimination *against*, we have thrown away discrimination *for*; to avoid barriers, we have thrown away hurdles; in pursuit of fun and happiness, we have praised effort but reduced challenge and depreciated achievement; we decry the falling test scores of students—but it is we who are weighed in the balance and found wanting.

Though we are deeply troubled by the problems of- and facing-chemistry education today, we are optimistic that the people will sense the hazard and support the changes that must be made. That would be consistent with the American character, no better described than by Alexis de Toqueville:

> "They [the Americans] have all a lively faith in the perfectibility of man, they judge that the diffusion of knowledge must necessarily be advantageous and the consequences of ignorance fatal; they all consider society as a body in a state of improvement, humanity as a changing scene, in which nothing is, or ought to be permanent; and they admit that what appears to them today to be good, may be superseded by something better tomorrow."

The Task Force trusts that that spirit continues to the present day.

We believe that education and disciplined learning, that provided a substantial base on which our society was founded, are critical to its survival. The study of the universe and of the creatures that occupy it are among humanity's noblest efforts and achievements. But, while such study has increased in depth and penetration, and its results have been used to change our lives at an ever increasing rate, education in science and technical fields has weakened and fallen behind the pace of applications. This situation may have existed always—but the disparity has become intense and critical in the last twenty years.

We believe that there are effective means that can be employed to restore the educational system to a viable state where it can serve more effectively the noble purposes we ascribe to it, but those means must be employed in an orderly fashion and consistently over a substantial period of time; we do not believe that a crash program can overcome the losses of past years in short order.

Such efforts will require a rededication of many individuals and units of our society to the goals and purposes of education. This rededication cannot be achieved in time now considered spare, or excess over an individual's normal duties, but must be part of those normal duties.

Since the time and effort of individuals are equivalent to financial resources of the community, substantial redirection of the use of those resources is in order, and, indeed, without such reallocation no progress will be made toward the desired long-term changes in the educational Establishment.

Thus, we call for redirection of the assets of time, money, and other capital of our civil and professional societies. We call upon the American Chemical Society to establish certain bodies, task forces, and staff offices to undertake certain studies and projects which we believe will prove healthful. We call upon the chemical industry for resources to sustain the educational programs on which its own future must depend. Above all, we call upon the State and Federal Governments to devote resources they derive from the society they administer to the sustenance of the future of that society through improved education.

Recommendations on NATIONAL CONCERNS

N1 National Council on Education in Science and Technology
N2 Sub-Council/Commission on Public Understanding of Science Technology
N3 Sub-Council/Commission on Precollege Education in Science and Technology
N4 Chemistry Literacy and the American Chemical Society

Photo: National Aeronautics and Space Administration

The public about whose understanding we are concerned is, in fact, all publics—the educated and uneducated in science, the voter and the politician, the child and the adult . . .

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N1: NATIONAL COUNCIL ON EDUCATION IN SCIENCE AND TECHNOLOGY

Recommendation: Formation of a National Council on Education in Science and Technology to coordinate and oversee national educational efforts.

There is deep concern about the impact of science on the "conditions of men," and growing anxiety that genetic science may affect the "sorts of men." How we react to these realities depends at least in part on what is commonly termed the *public understanding of science*: how that understanding came to be and what it might be in the future depend on the ongoing processes and content of *education in science and technology*. We believe that these two are inextricably bound up with each other.

Effective communication is a basic personal need. It is also a critical societal need. In both domains, the first prerequisite is common understanding. It is no longer arguable that effective communication about science between important sectors of the population is in a state of collapse. Neither science nor technologies based on it seem likely to wane in their significance to the national life and welfare. If decisions relating to that significance are to be made democratically and wisely, steps must be taken to improve the general, the public understanding of science.

Understanding of science has many levels and dimensions: for example: (1) understanding of what science is, and what it is not, including some knowledge of the scientific approach to matters known and unknown; (2) knowledge of some of the basic elements of science, including some of the fundamental scientific constructs; (3) the ability to function effectively as a citizen in the contemporary technical environment; and (4) knowledge of "organized" science—*e.g.* basic science, applied science, and development—and information about the impact of science on the individual and on society through decision-making and policy formation.

The *public* about whose understanding we are concerned is, in fact, all publics—the educated and the uneducated in science, the voter and the politician, the child and the adult—because they, in various ways, comprise the four strata into which issues divide a population: the decision-makers, the policy makers, the attentive (and, one hopes, informed) public, and the non-attentive (and, one fears, ill- or mis-informed) public.

Any benefits that accrue to society and any hazards to which it is exposed because of the uses to which science is put will depend on value judgements made by the public or in its name: by citizens-voters, by public representatives whom they elect, or by public officials whom they permit to be appointed. Those value judgements can be no better than the capacity of the judgement maker to understand and weigh the consequences of what are sometimes manifold and complex scientific and technical options. This is the public policy dimension of the public understanding of science.

There are other dimensions of the public understanding of science; a major one is economic. Contemporary society is based increasingly on the fruits of scientific and technical discovery and endeavor. The world around us is changing at least as rapidly as ever before and in easily discernible ways. Both the quality and quantity of the national life depend on the adaptive capacity of the people, and that capacity is undesirably low in science-based areas. The risks are that necessary adaptation will be impressed on those who cannot understand and change, and that thereby the general interest will not be served. It is critical to our national life that there be wide, informed, and intelligent participation in the determination of public issues. The need in areas related to science is at least as great as that in any other.

Whatever is the quality of the present public understanding of science, it will be affected not only by what is done to improve it directly, but by what the understanding and sophistication are of young people who join the adult public as they complete their education. It is important that a capable and credible voice be developed which can speak to government, to the academy, to industry, and to the people in effective ways about the quality and quantity of education in the schools for citizens and about the preparation received there by students who will go on to more advanced education in science or a science-related field.

N1. A National Council on Education in Science and Technology should be formed to coordinate and oversee educational efforts at all levels in science and technology—both for the general education of the population and for the practice of such specialties. In recognition of the size and complexity of the task of improving education in science and understanding of it, two sub-Councils should be formed to deal with: (1) the public understanding of science and technology; (2) pre-college education in science and technology.

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a. The proposed National Council, if not created and supported by an appropriate office or officer of the United States Government, should be founded by representatives of the major scientific and technical societies and, at least initially, funded by them.

b. Such a National Council should be a pan-scientific body. Ways might have to be developed early to control its size, lest it become a "congress" unwieldly in numbers, but the National Council membership should include representation from scientific discipline societies (e.g. American Chemical Society, American Physical Society), disciplinary area organizations (e.g. American Institute of Biological Sciences), pan-scientific organizations (e.g. American Association for the Advancement of Science), science teaching associations (e.g. National Science Teachers Association, American Association of Physics Teachers), among others. It is important that the Council be representative, so that the interpenetration and interdependence of the various technical disciplines be turned to advantage and that articulation be improved.

c. The Council should stimulate, study, coordinate, and oversee policy development and activities concerned with: (1) the public understanding of science and technology and of their interactions with society; (2) the improvement of the science and the science-related components of precollege education.

In later sections of this Report, this Task Force proposes a number of responsibilities for the National Council in less global terms. At those points appropriate detail will be given of suggested approaches and structures. Here we emphasize the *national* and *council* aspects. A similar council with somewhat broader responsibilities was proposed by The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology.

N2: SUB-COUNCIL/COMMISSION ON PUBLIC UNDERSTANDING OF SCIENCE/TECHNOLOGY

Recommendation: Formation of a sub-Council on Public Understanding of Science and Technology.

The preceding section proposes a national council that would coordinate the public and professional aspects of education in science and technology through two sub-councils—one devoted to the work of the formal educational system, the other devoted to the processes of communication to and education of the general public. Presumably, the council and the sub-councils would be created in the same way.

Science is popular fare these days: witness the rapid increase during the last two years in the number of periodicals devoted to bringing to a presumably numerous and widespread audience sound writing and pictorialization of the progress of science in many areas; witness the significant and steady increase in the number of television programs devoted to scientific subjects. Yet one wonders if the speech from those pulpits is not sermons to the committed. The understanding of science that languishes today is not that of the educated or attentive citizen whose interest has already been gained, it is that of the unaware, inattentive citizen who has not been engaged.

There has been substantial interdisciplinary cooperation in a number of efforts to improve the public understanding of science and the impacts of science and technology on society and the human condition. Such activities have involved elements of the media, industrial, institutional, educational, and scientific Establishments with little or no coordination. While one would not wish to place a heavy controlling hand on such efforts, one might well hope to improve their efficiency and effectiveness by fostering their coordination.

In part, concern that the public understanding of science and technology is not as good as it should be arises in the belief by science-literate persons that the quality of public participation in the making of science-related decisions is poor: non-science is not distinguished from good science; the unscientific masquerades too easily as supportable and true; the declared absolute is heard and respected while the never-completely-certain reality is unwanted and rejected. The science-literate see in these signs the possibility of stampede instead of sound judgement in the development of solutions to those problems of society that relate to or derive from science and technology.

N2. Whether or not a National Council is formed, the equivalent of its sub-Council or Commission on Public Understanding of Science and Technology must be formed. This body should provide stimulation, study, coordination, and evaluation of a wide variety of activities designed to improve and advance the public understanding; it should be an advocate for a needed change.

a. Such a sub-Council or Commission should include not only representation from the several domains of professional science [scientific discipline societies, disciplinary area organizations, pan-scientific organizations, science teaching associations, and others], but membership drawn from the information community [media experts (print and electro-optical), communications organizations (e.g. American Museum Association, National Association of Science Writers, American Library Association, Corporation for Public Broadcasting), etc.], major support agencies [National Science Foundation, Department of Education, the private foundations, and others], and major industries and industrial organizations.

b. The initial responsibilities of this sub-Council or Commission should include: (a) working with the National Science Foundation and the National Assessment of Education Progress to establish programs for measuring the national, regional, and perhaps even state levels of public understanding of science; (b) working with various groups to develop a system for collecting and reporting information on the public understanding of science and technology; (c) developing programs for evaluating and reporting on the total national effort on communication of science and technology to the public and the related improvement in public understanding. In addition, this sub-Council or Commission might: (d) sponsor or convene national and regional conferences on various aspects of communicating science to the public; (e) sponsor the establishment of a National Center for Public Understanding of Science which would serve as a stimulating focus for research and development of a multi-disciplinary character.

N3: SUB-COUNCIL/COMMISSION ON PRECOLLEGE EDUCATION IN SCIENCE AND TECHNOLOGY

Recommendation: Formation of a Sub-Council on Precollege Education in Science and Technology.

No nation has turned so consistently, so forcefully, and so broadly to education to prepare its people for informed participation in democratic processes as has our own, nor is it likely that that reliance will diminish in the future. The present widespread mis- and dis-understanding of science is due in part to the rapid expansion of scientific knowledge and to the acceleration in the rate at which new knowledge is applied to the things and matters of everyday life. But, it is also due to the failure of the processes and (likely) the Establishment of education to keep pace with that expansion and acceleration. It is fruitless to attempt to fix blame for the present situation. The more important task by far is to restore health to the public understanding of science, and attention to education is a major portion of that task.

Complex modern society demands that science and technology be both used and understood. The same educational apparatus that provides the underpinning for the general and public understanding of science is responsible also for the early schooling of those who will progress from the learning to the "doing" of science—to the discovery of knowledge that later will be put to use.

The concern of the people for the state of the nation's schools and the educational tasks they are supposed to accomplish has led to the formation of a number of bodies charged to study the national system of precollege education and report their findings, plans, and recommendations for action. Foremost among such bodies are The National Commission on Excellence in Education and The National Science Board Commission on Precollege Education in Mathematics, Science and Technology, both of which issued extensive reports in 1983. As will be seen later, the recommendations of this Task Force echo and build in many ways on the findings and proposals of those two Commissions. We believe that the needs they have identified must be addressed, that the tasks they have set must be accomplished, and that the momentum of their efforts must not only not be lost—it must be translated into continuing oversight of the state of the nation's efforts and progress in science, mathematics, and technology education.

N3. Whether or not a National Council is formed, the equivalent of its sub-Council or Commission on Precollege Education in Science and Technology must be formed. This body should provide continuing oversight and evaluation of a wide variety of activities designed to improve and strengthen precollege education in science, and technology; it should be an advocate for needed change.

a. Since this body is intended to both inherit the mantles and to continue bearing the burdens of The

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National Commission on Excellence in Education and The National Science Board Commission on Precollege Education in Mathematics, Science and Technology in the areas of science and technology, at least, it is best that its composition reflect theirs, with appropriate additional emphasis on expertise from the several technical disciplines.

b. The initial responsibilities of this sub-Council or Commission should include: (a) working with the National Science Foundation and the Department of Education to develop Federal, state, and local support for efforts to improve the qualifications of present teachers; (b) working with Federal, regional, and state education agencies, and with the professional technical and teacher organizations, to coordinate and improve present systems for assessing the quality of precollege education in science, mathematics, and technology; (c) developing programs for evaluating and reporting on the total national effort to improve and strengthen precollege education in science (including mathematics) and technology.

Virtually every individual or group that has reported a recent study of the problems in science education has proposed the formation of a national body to spearhead improvements. While agreeing that the Federal Government will play a central role in such efforts, the several studies have proposed different compositions, authorities, and placements with respect to the Government of this national leading body.

A major recommendation of *The National Science Board Commission on Precollege Education in Mathematics, Science and Technology* is that the President of the United States appoint immediately a "National Education Council made up of representatives from a cross-section of national interests." This Council would "provide leadership in developing, coordinating and implementing plans to improve and maintain the quality of the Nation's elementary and secondary education in mathematics, science, and technology."

On a continuing basis, the National Education Council would "identify educational goals and recommend the changes needed in the form and content of education to reach these goals; ensure that (an) assessment mechanism . . . is developed and maintained for measuring and comparing student achievement, participation and progress toward these goals in every state, school district and school; . . . monitor and report anually to the American people on the status of American education and progress toward achieving these educational goals . . . facilitate the sharing of information about successful mathematics, science, and technology educational programs . . . and recommend incentives to encourage state, local and private investment in education."

[The Commission recommended annual appropriations of $2.75 million to support the Council and $5 million to finance the assessment mechanism.]

The National Council that this Task Force has proposed differs from that described by the NSB Commission in two principal respects: ours would be an independent body rather than a unit of the Executive Branch; and, its responsibilities would include both precollege education and the more diffuse matter of the public understanding of science.

A distinct advantage of the Commission's proposed Council is that it *could* be given real coordinating authority extending beyond what are essentially advisory roles—and such authority may be important if Federal support is to be deployed with maximum effectiveness. An important strength of the Council we propose is that it would deal with the understanding of science by present citizens as well as future ones.

The National Science Foundation and the Department of Education are the Federal Agencies with major capacities and/or programs in what might be termed civil science education. There have always been a certain amount of tension between the two over their respective roles. Those who believe that the National Science Foundation should support programs as close as possible to the research frontier have opposed its high school (and sometimes college) teacher education activities in mathematics and science, preferring that the Department of Education be the responsible agency; similar preference has been expressed by those who see nothing special about science and mathematics as school subjects.

This Task Force agrees with the NSB Commission that the National Science Foundation "has recognized expertise in curriculum development," and that its summer inservice institutes "provide a proven model for the upgrading of teacher skills." The National Science Foundation can draw upon the ingenuity and resources of the scientific community to solve problems in science education; further, it has been very successful in strengthening the competence of teachers whose duties are centered strongly on disciplinary subject matter—i.e., college and high school faculty members.

On the other hand, the Department of Education is much more practiced in reaching the vastly greater number of elementary, middle, and junior high school teachers, whose duties are usually more diverse and whose professional preparation is less strongly focussed—and, as we will note later, may be very deficient in science content.

To coordinate science education-science educator activities of the National Science Foundation and the Department of Education, a *National Science Education Board* could be created within the Executive Branch of the United States Government as an interagency unit; in addition, such a Board could play the informed conscience role envisioned by the NSB Commission. It could easily, "identify, recommend, monitor, and report," but it would be very difficult for such a body to "facilitate and ensure" unless it had additional authorities (suggested in Recommendations N1–N3) to "study, stimulate, oversee, evaluate, *and coordinate.*"

To the degree that its powers would depend ultimately on control over the purse, a National Science Education Board would have to have authority to direct and coordinate those fractions of their annual appropriations that NSF and DOE are authorized to expend on science education. And, in that sense, it would be an operational as well as an advisory body. A National Science Education Board so situated and so empowered could be a highly effective spearhead for the many activities envisioned for its counterpart by the NSB Commission, and it could play a strong intiating and directing role with respect to the numerous teacher, curriculum, and instructional materials improvement activities described in later sections of this Report.

N4: CHEMISTRY LITERACY AND THE AMERICAN CHEMICAL SOCIETY

Recommendation: Strong ACS participation in these efforts.

Physicists have expressed concern over the "mad scientist" image of them that is frequently projected by the media, and, justifiably, chemists are tired of their image as despoilers of the world. The public is very much aware that "chemicals" pollute some portions of the environment, and very little aware that their lives are chemical. The public is caught up with the potential of genetic manipulation for improvements in human health and crop yields, but does not know that genetic "engineering" *is chemistry*—pure and not-so-simple. The content and balance of the chemistry component of the science literacy of the general population need attention.

The American Chemical Society budgets several hundreds of thousands of dollars annually for activities designed to improve the public understanding of science in general and chemistry in particular. The Council Committee on Public Relations, Joint Board-Council Committee on Chemistry and Public Affairs, and Board Committee on Public Affairs and Public Relations have important oversight responsibilities. The Education Division, Department of Public Affairs, and the Office of Public Relations, all three of which are staff activities, mount numerous programs that seek to improve aspects of public understanding. And several member groups, such as Corporation Associates and the Division of Chemical Education, are vigorously active in the area.

This Task Force believes that there is at present too little coordination of the Society's activities designed to improve the public understanding of chemistry. Public-oriented and education-oriented efforts interpenetrate each other, but there is little reflection of this reality in the way the Society's programs operate.

N4. Within the American Chemical Society, a committee or task force (perhaps ad hoc) on public understanding of chemistry should be formed to: (a) provide the input for chemistry to the proposed National Council (N1) and its suggested sub-Council or Commission on Public Understanding (N2); (b) provide coordination and oversight of ACS activities in this area; and (c) establish a sub-unit to give needed attention to the implementation of the Society's educational efforts directed to non-scientists.

a. This Task Force believes that the American Chemical Society should place additional emphasis on its activities as a direct interpreter and adviser to Congressional and administrative decision-makers, and that it should expand its efforts to provide information to interpreters and popularizers of science. An appropriate ACS body should determine whether there are needs and opportunities for mass communication to the public that should be met by allocation or re-direction of Society resources.

The sub-unit mentioned in N4(c) is urgently needed. Whether it be a subcommittee of the Society Committee on Education or a staffed Office within the Education Division, or both, is less important than the creation of the focus.

Recommendations on ALL LEVELS OF EDUCATION

A1 Improving the Qualifications of Today's Teachers
A2 Information Technology and Science Education
A3 Research in Science Education

Photo: Phyllis Marcuccio

One of the views held by members of this Task Force is that good teachers know something about the teaching arts AND about what they teach.

A1: IMPROVING THE QUALIFICATIONS OF TODAY'S TEACHERS

***Recommendation:* Vigorous and large expansion of National Science Foundation and other Federal programs to upgrade the quality of science instruction through direct service to teachers.**

This report of the recommendations of the Task Force is, we hope, colored strongly by our concerns for quality—in particular for the quality of the educational experiences that students have. At some levels of education we know exactly how to pursue that quality, primarily because there is agreement on what it is. At other levels of education it is more difficult to address the issue because there are differing views of it. Some measure quality by how the students feel about what they have learned; some by what the students have learned; some by how the students feel about themselves while learning or after having learned. Since the learning for which we have a care is being done by flesh-and-blood human beings, not by intelligent automata, all of these dimensions and others as well are important.

It is important also that we maintain awareness that there is an ever-changing mix (varying with time, discipline, and individuals) of what is taught and what is learned, of what is teaching and what is learning. However we learn, it is important that the quality of the teaching be as high as possible.

One of the views held by the members of this Task Force is that good teachers know something about the teaching arts AND about what they teach. Since teaching and learning have powerful behavioral aspects, it is easy to feel accomplishment and satisfaction when one masters the arts, techniques, and some of the science of teaching and learning. But, just as an engine produces no work unless fueled, so the arts of education produce no learning unless fueled with knowledge. At too many levels, in too many places, about too many subjects, those who teach do not have sufficient or new enough knowledge of subject matter to assist sound learning.

We do not attempt to fix blame for this state of affairs. We simply assert that present teachers must be helped to improve the base of knowledge upon which they stand to teach. Further, we assert that although some weakness of the present foundations of teaching may arise from imperfect art, much of it arises from outdated or insufficient content.

During the 1960s and until rather recently the United States Government supported a number of programs designed to assist high school and college teachers of mathematics and the sciences to update and extend the disciplinary knowledge on which their teaching was based. There were summer institutes for both high school and college teachers, science faculty fellowships, and several programs of grants for conferences and short courses. There were consultant and visiting scientist programs, instructional scientific equipment grants, college science improvement programs, grants for summer research for undergraduates, etc. These programs started at the teacher-discipline interface and spread to work on curricula, provision of instrumentation, fostering faculty and student research activities, and a variety of other ways of initiating and maintaining the momentum of knowledge and skills improvement by individual teachers.

Funding for these programs eventually all but disappeared. There were concerns about their effectiveness, particularly their cost effectiveness. Some of the curriculum projects ran onto shoals of various kinds. It was difficult to demonstrate positive results of a cluster of programs whose aggregate costs were several hundreds of millions of dollars. Retrospection has given us a different view: If nothing else, the teacher development programs of the National Science Foundation arrested and for a time reversed the nationwide decline in the quality of science instruction that began before them and continues after; in education as in athletics, continuing capability depends on continued coaching and training—one has to run in order to stand still; and, those programs were among the most effective educational coaching and training efforts ever devised or implemented.

We think it important that there be a continuing national effort to sustain teacher vitality and to motivate the changes in chemistry education at all levels that are necessary in response to the continuous development and change in the discipline. But, the times now demand much more than service to just this important objective.

In some later recommendations we will argue for increased emphasis on science in the primary and elementary grades, both to build in a constructive way upon the natural curiosity of children and to assure that from the earliest years a foundation is slowly and carefully built that will help assure that those choices and decisions related to the facts and methods of science that every citizen is called upon to make or support are wise ones. In other recommendations we will stress the need for more and better student contact with science in secondary schools and in higher education.

If our recommendations for high school and collegiate curriculum content are received favorably and implemented widely, a larger fraction of new teachers should have the knowledge and skills they need to help students meet and learn science at every level of education. In the meantime, today's teachers need help—and lots of it—if several more generations of students are not to be under-educated (or, worse, dis- or mis-educated) in science. There are many ways to help today's teachers: workshops, conferences, and other in-service activities can reach many in a short time; summer or semester-long institutes can provide new background and updated experience for those requiring more thorough work; materials development and curriculum assistance are important too.

A1. The Chemistry Education Task Force recommends a vigorous and large expansion of National Science Foundation and other Federal programs to upgrade the quality of science instruction through direct service to teachers. Such programs should include not only college and high school faculty members (who were well served by earlier programs of the Foundation) but also elementary school teachers and those specialists in science education at all levels who will bear responsibility in improving the science literacy of the student and general populations. We recommend also that state and local governments match the federal contribution by facilitating and supporting teacher participation in such programs and, in due course, by developing their own systems for assuring teacher improvement and refreshment.

The National Science Board Commission on Precollege Education in Mathematics, Science and Technology has proposed a program of summer and in-service institutes for teacher improvement that would expend $3.49 billion over a five year period. It was proposed that Federal support be half the total, the other half being provided by the states on a matching basis.

The recent transfers of some costly Federal programs to state funding make it unlikely that the states will accept this particular education obligation on the scale that is necessary, even if the effort could be limited to five years. We believe that a program of this kind is a national need and therefore should be a Federal responsibility. Further, the program should be a permanent one, addressing a succession of priorities as changing circumstances warrant.

There are neither the faculties nor the facilities to achieve the objectives of the Commission's proposed program in just five years. A permanent cluster of efforts could be phased-in over a period of 4-6 years, however. Federal funding should be of the order of $200-250 million each year. The states' "match" of these funds will be indirect—higher teacher salaries, support of facilities improvement, provision of more adequate equipment and supplies, etc. Such things might be required of the states, rather than the shared support of direct costs envisioned by the Commission.

A2: INFORMATION TECHNOLOGY AND SCIENCE EDUCATION

Recommendation: Expansion of Federal support of research and development in the use of computers and other information technologies in science education.

Modern information technology—computers, video recording devices, inexpensive electro-optical means of storing and transmitting information, etc.—is creating a wide-reaching revolution in the conduct and even the nature of human affairs. Work, recreation, and education are all being affected profoundly.

For example, the computer is changing quickly and drastically the ways in which commerce and industry are done and the nature of many jobs. It has enhanced greatly the effectiveness of scientists and increased the scope of scientific investigation. The new world created by the computer makes new demands on science education and, fortunately, affords the means to meet these and other educational demands. The whole science curriculum, from elementary school onward, must be changed to prepare students to use computers at work and at home as well as in the classroom and laboratory.

The range of computer applications to science education is enormous: simulations of the behavior of chemical systems; mammoth database capacity; networking of individuals, libraries, and databases; diagnosis of the individual student's current knowledge, mental models, and problem-solving strategies, permitting teacher-tailoring of appropriate learning activities; tireless tutoring; etc.

The changes in school programs that can be made because of these applications cannot be easily or lightly undertaken. All of them, to some extent, put the student and teacher at the mercy of the programmer: simulations assume that the programmer knows what is going to happen; diagnosis is based on the programmer's knowledge of syndromes and judgments concerning their elements. Schools must have guidance based on research and development if they are to be confident of the educational effectiveness of various innovations now possible and if the advanced possibilities that go well beyond present practice are to be explored carefully. Some of the necessary research and development will be carried out in the private sector. But, since private and public purposes to not always coincide, there is need for the United States Government to provide support here, as it does in other areas important to the national interest.

A2. The United States Government should continue and expand its role as a major supporter of research and development in the use of computers and other information technologies in science education, including the establishment of a research and development center to explore the potential of information technology in science education.

a. At present, the National Science Foundation and the National Institute of Education are the main Federal vehicles for provision of support for research in science education. It is likely that the Department of Defense and other Federal agencies, however, are sponsoring research and development work that have substantial application to education. All such agencies should increase the number and expand the support of joint or cooperative research projects that bring together physical and life scientists, teachers, computer scientists, and cognitive scientists to study and develop educational applications of information technology. Because of the number of different disciplines involved in such activity, we propose that the Government establish a demonstration research and development center to explore the potential of information technology in science education for all students.

A3: RESEARCH IN SCIENCE EDUCATION

Recommendation: Expansion of Federal support of research in science education.

The increased emphasis on providing substantial science education to *all* students brings forward questions about the proper objectives of education in science for the general student who will not seek a career in science, how well these objectives have been achieved in the past, and how such achievement can be improved in the future.

Two major objectives of science education are the growth of understanding of basic scientific principles, and the development of the ability to use these principles in reasoning about scientific matters and in solving problems that arise at work and in daily life. Content and subject matter are of critical importance to such growth and development and it is makeshift to rely instead on the short cuts which simulation and algorithmic learning seem to afford.

Research in cognitive science has entered a new and fruitful phase, yielding knowledge that can improve the learning of science by both the general student and the student interested in a science-related career. Cognitive scientists, in collaboration with scientists and teachers in several disciplines, have shown, for example, that students enter upon science instruction with their own mental models of the phenomena that are studied. These models, based on previous observation and experience, are often erroneous, and, like myths, are remarkably resistant to modification, and often remain dominant when science instruction has been completed.

Research on problem solving has shown that novices and more expert persons use quite different approaches: an expert first analyzes the problem in terms of the principles involved, then turns to mathematics to complete the solution; the novice typically seeks immediately a formula connecting the data provided, and is often at a loss if none can be found.

The scientists and teachers pursuing this research believe that a central objective of science education should be to help students develop correct mental models of phenomena (this requires specific attention to modifying the tenacious erroneous models the students bring with them) and to turn to these models rather than to rote formulas when confronted with a problem to be solved.

These and other conclusions that continue to emerge from new research in science education suggest strongly that substantial modifications are required in existing curricula, teaching practices, and teacher education programs. It is in the national interest that these changes be made and that further research along these promising new directions be supported. As in other areas of national importance, the principal source of research support in science education must be the United States Government.

A3. The United States Government should continue and expand its role as the principal supporter of research in science education, especially through efforts that increase the interactions between and among scientists, science educators, and cognitive scientists.

a. At present, the National Science Foundation and the National Institute of Education are the main Federal vehicles for provision of support for research in science education. These two agencies should increase the number and expand the support of joint or cooperative research projects which bring together teachers, scientists and mathematicians concerned with teaching in their disciplines, and cognitive scientists. Such projects have proved very fruitful in increasing our understanding of both the learning and teaching of science and in suggesting ways to improve them.

b. The Education Division of the American Chemical Society, the corresponding units of other disciplinary associations, and the proposed National Council (N1 and N3) should encourage both the expansion of Federal support of science education research (particularly that involving cognitive science) and the careful application of the results of such research to curricula, in the classroom, and in the education of teachers.

Recommendations on ELEMENTARY SCHOOL SCIENCE

E1 Scientific Societies Effort in Aid of Elementary School Science
E2 Reading, 'Riting, 'Rithmetic, and Rscience
E3 Guidelines for School Science Curricula
E4 Elementary School Teachers of Science
E5 Federal Regional Science Centers
E6 ACS Activities in Pre-High School Chemistry Education

Photo: Charles Frizzell Photography

> First and foremost, introductory science should be based on the observation of phenomena and discussions of possible causes.

E1: SCIENTIFIC SOCIETIES EFFORT IN AID OF ELEMENTARY SCHOOL SCIENCE

Recommendation: Coordinated effort by scientific and engineering societies to address the major problems of science education in the elementary schools.

> "The principal goal of education is to create men and women who are capable of doing new things, not simply of repeating what other generations have done . . . who are discoverers. We need pupils who are active, who learn early to find out for themselves, partly by their own spontaneous activity and partly through the materials we set up for them." [Jean Piaget (1896–1981), educational psychologist]

Convincing research suggests that a great many young people lose their early curiosity about natural phenomena and develop negative attitudes about science before they reach high school. Yet, some teachers do generate and maintain enthusiasm for science in their students; some schools and school systems produce more science-interested students than others; and many high school graduates are science-literate and have demonstrably acquired that literacy over years of schooling. A suitable curriculum, attention to the individual needs of learners, and teachers who themselves have developed and sustained some enthusiasm for science, can produce students who, at every stage of their progress through the schools, have appropriate knowledge of science, have continuing opportunities to develop an interest in science as a career area, and are becoming sufficiently familiar with science to use it as background for their adult lives.

That the state just described is not universal may arise (ultimately) from unfortunate attitudes such as: lack of parental concern and support for learning, lack of student motivation, and widespread undervaluing of intellectual growth and achievement. These factors and others have created three major barriers to the improvement of elementary school science instruction and the bettering of the attitudes of children toward science:

1. The barrier of insufficient time—20 minutes or so of each school day (about the national average) is not enough;
2. The barrier of presently inadequate curriculum—in spite of a national effort at curriculum improvement some years ago;
3. The barrier of teachers ill-prepared to teach science and encourage students in science.

Later in this section, the Task Force will comment on each of these areas in more detail.

Over the past twenty years, the National Science Foundation has funded a number of science curriculum projects for elementary schools, including: *Science, A Process Approach*; *Science Curriculum Improvement Study*; and *Elementary Science Study*. Evidence of the extent to which the products of any of these NSF-supported projects have been or are being used in elementary schools varies depending on the report and level of analysis; however, these new curricula in aggregate have never reached as many as a third of the elementary school population at any time, and their use has slowly waned as follow-up and refreshment funding has disappeared.

Science is an incidental topic in most elementary school curricula, and it is no surprise that school administrators and teacher certification bodies have paid little attention to the need to qualify teachers to communicate science in an accurate and effective manner. The same status is among the factors that have produced the present under-emphasis on this subject area which looms so large in the life of the nation.

Making a substantial improvement in the quality of elementary school science education will be a formidable task, but it must be done. New resources and new energies must be brought to bear on the task. It is not enough to start with alarm and finish by "giving everyone the same little bit to bring about the same little change." This Task Force believes that the nation's associations of qualified technical professionals have a responsibility to provide both guidance and participatory leadership to a national effort to raise the quality and quantity of the science instruction received by our children.

E1. A coordinated effort by the American Chemical Society and other national scientific and engineering societies should be mounted to address three major problems of science education in the elementary schools: the insufficient time devoted to it; the less-than-desirable quality of the curriculum and educational materials; and the lower-than-necessary qualifications and preparation of the teachers charged with direct responsibility for it.

a. This effort could be led by the American Association for the Advancement of Science, which has long given special attention to science in the schools. Educational societies, such as the National Science Teachers Association, could play important roles also.

b. The centrality of chemistry to its sister sciences and the importance of chemical phenomena to every aspect of daily life require that there be a chemistry component to science instruction at all grade levels; chemistry is too important to be left until there is time for a "unit" or "mini-course" in the middle or junior high school curriculum, or for a "course" in high school. Leadership in this aspect of the national task is appropriately that of the American Chemical Society through instruments such as the (governance) Society Committee on Education, (staff) Education Division, and (membership) Division of Chemical Education.

c. We recommend that state and local teacher certification be dependent on regular participation in subject matter-oriented educational activities such as workshops and institutes, as well as on similar efforts directed toward improvement of skills and methods.

E2: READING, 'RITING, 'RITHMETIC, AND RSCIENCE

Recommendation: An immediate national effort by scientific and engineering societies to add science to the present basic triad of school subjects.

The remarkable success of "American" scientists in achieving the levels of insight, ingenuity, and indefatigability that lead to Nobel Prizes has been ascribed to everything from the flight of scientists from Nazi Germany to the superiority of the entrepreneurial climate fostered by the way science is organized and supported in the United States. But, few indeed are those who have laid the laurel wreath at the foot of the American school system.

The purpose of science education in the elementary schools ought not to be to assure future Nobelists of appropriate initial preparation, but it should not cut off that possibility. The purpose ought not to be to initiate the intense pre-career contact with science that might benefit students who are as excited about natural phenomena as some youths are about basketball, but neither should their excitement go unanswered or even unstimulated. The purpose ought to be to give every student an understanding of what science is and is about that will permit, not inhibit, encourage, not discourage, and provide a foundation for that entirety of school-taught science that is foundational to effective citizenship.

There is too little science of any kind taught in elementary school. Since little science is taught, few students get enough exposure that responds to their interest and curiosity if they have it, or stimulates it if they do not. The results are poor awareness of science and poor discrimination with regard to science-based matters arising in adult life—poor preparation for meeting the demands of life in an increasingly technologically-oriented environment—and many fewer students interested in science-related careers than is in the national interest.

Comparisons with the patterns in European countries reveal some of our shortcomings in elementary level science education. *They* devote 25–30 percent of class time to instruction in science and mathematics, in a school year averaging 240 days of 7–8 hours contact; *we* spend 20–25 percent of class time in such instruction, in a school year averaging 180 days of about 5 hours contact. Japan perceives that it is in the national interest to provide advanced education in science and engineering to two to three times as many students as are necessary to meet immediate employment demands, believing, apparently, that the worker in a nonscience profession who has a science background makes a positive contribution to the national welfare, including the gross national product. The patterns of American education, by contrast, are increasingly driven by short-term vocational forces.

E2. The American Chemical Society and other national science and engineering societies should begin an immediate national effort to add science to the present basic triad of school subjects—reading, writing, and basic mathematics.

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a. It would help to increase to 25–30 percent the proportion of the school day that is devoted to instruction in science and mathematics. Substantial improvement would also be attained if the percentage were maintained while the school day were lengthened. Mathematics already has 45 minutes of the elementary school day; it is the time devoted to science instruction that must be increased.

b. One sure way to assist the increase of attention to science instruction in the elementary school curriculum is to expect science achievement on the part of all students. Therefore, the testing of science learning must be made a major part of any program of assessment of student progress. Achievement testing is, however, but one of the mechanisms which must be employed to assure the *quality* and *content* of instruction in science (and in every other area); the nation does not need more time devoted to pap.

Finally, we observe that students can be required to *read and write about science*; no sacrifice of learning of communication skills is necessary in order to increase the efforts in science and mathematics.

E3: GUIDELINES FOR SCHOOL SCIENCE CURRICULA

Recommendation: Development of model science programs for each grade level K-8

A chemist thinks immediately of certain concepts and facts that ought to be taught to elementary school students; a physicist, biologist, astronomer, or geologist might draw up a rather different list. There is certainly no single best way to expose school children to science, but there are certain features of that exposure on which most scientists would agree. First and foremost, introductory science should be based on the observation of phenomena and discussion of possible causes. Second, students should be given the opportunity to carry out simple experiments (and watching the growth of a planted seed is an experiment if a second seed is planted or grown under slightly different conditions).

It seems safe to say that all physical scientists would agree that one important aspect of school introductory science is the observation of quantitative relationships (larger/smaller, less/more, faster/slower), and that another is the observation of changes in properties (color, physical form, energy content, solubility). It is doubtful that elementary school students should be prepared specifically for the wave mechanics presently (and inappropriately) introduced in the high school, but the particulate nature of matter is something that they should be led to understand at an early stage.

In brief, there are many descriptive and conceptual matters that can and should be introduced to all students through well-designed and well-considered elementary school science curriculum elements.

E3. A model science program for each grade level K-8 should be developed under the auspices of the National Council (N3), with each major science society assuming responsibility for assisting the creation of curriculum guideline components in its disciplinary area. It is critical that science instruction in the elementary grades be based on observation of phenomena, and that it contain descriptive, quantitative, and conceptual elements.

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a. As part of its participation in the proposed national effort (E1), and consistent with the objectives of the present recommendation, the appropriate units of the American Chemical Society should sponsor the development of chemistry modules for each grade level with special emphases on ease and safety of use and on low cost.

b. This Task Force recommends that the American Chemical Society and its sister science and engineering associations join to inform the public of the need for observation-based elementary science education so that the local and state financing bodies will be supported in their quest for the additional funds that may be required to equip classrooms and provide instructional kits for such "hands-on" science in the schools.

E4: ELEMENTARY SCHOOL TEACHERS OF SCIENCE

Recommendation: Development of guidelines for certification of elementary school teachers to teach science.

There is a critical shortage of teachers who are qualified to teach the science that ought to be in the elementary school curriculum. Few teachers who do teach science in elementary schools are well prepared to do so. Neither the fiscal nor psychological rewards of school teaching are adequate or appropriate. Teachers with skills marketable outside education are easily tempted into other and more rewarding careers.

Half of the 45 leading teacher education institutions require 8 semester hours or less of college-level science in their elementary education curricula. In one large school district in a relatively wealthy state in the Southeast, 12 percent of the teachers of elementary school science had taken no college-level science at all before starting master's level degree work in education, 20 percent had taken no course in the methods of science or the methods of teaching science, and 65 percent had never attended an in-service seminar or workshop on science teaching. In many states, elementary and middle school teachers can be certificated with as little as one college-level science course, and in most states there is no certification requirement of coursework in methods of teaching science. Among teachers, the level of expression of self-confidence to teach the material in the curriculum is a fifth to a third as high with respect to science instruction as it is with respect to instruction in reading, social studies, or (even) mathematics.

E4. This Task Force recommends that the National Council (N3), with respect to the development of model K-8 science programs under its auspices, set forth guidelines for certification of elementary school teachers to teach science; and, we recommend that those guidelines require of such teachers before certification the successful completion of at least 3 one-year courses in the sciences, a balanced selection being required among courses in the biological, earth, and physical sciences.

a. Further, we recommend that the National Council and its component scientific and engineering societies mount programs of public information in support of the changes in conditions of employment of elementary school teachers which, in fairness, should accompany more stringent requirements for their professional certification—changes such as: compensation competitive with alternative careers, scholarship, tax preference, and other financial inducements to enter and remain in teaching, salary schedule advancement and tuition assistance for subject matter continuing education in addition to that derived from methods education and longevity, and released time for the special preparations that are necessary for the safe and effective teaching of science to children.

b. We recommend that elementary school teachers with a specialty in science, perhaps as members of a teaching team, be used to provide sound instruction during the period in which individual classroom teacher preparation for science instruction is being brought up to adequate levels.

c. Finally, we urge the participation of present elementary school teachers in programs designed to improve their knowledge of science and science teaching (A1).

E5: FEDERAL REGIONAL SCIENCE CENTERS

Recommendation: Establishment of Federally supported Regional Science Centers as focal points for improvement of precollege science education.

Curriculum guidelines and increased teacher certification requirements will be regarded as *hurdles* by some who, otherwise, agree that steps must be taken to improve the quantity and quality of elementary school science teaching. Further, there is no doubt that such components of a general remedy have a long-range but slow-acting aspect. *Help* is needed in addition for those who presently teach in elementary schools, most of whom will continue to do so; help that, though continuing, is shorter-range and faster-acting.

This Task Force believes that two kinds of help would be especially useful: (1) assistance to teachers in the form of new curricular and instructional materials; (2) assistance to teachers in the form of educational activities and experiences for them designed to strengthen their knowledge and understanding of science and of recent research findings on the effective teaching of science, and to strengthen their self-confidence to present science and supervise student activity in the classroom.

To these ends:

E5. As many as ten Regional Science Centers should be established and supported by the United States Government to provide focal points for the improvement of precollege science education through teacher service programs, curriculum and materials development projects, the provision of expert consultation, etc. The small permanent staff of each center should be strongly discipline-oriented, and each center should serve several disciplines selected in view of regional needs.

a. It would be appropriate that the National Council (N3) (a) direct the selection of the host institution for each such center by formulating the selection criteria and in other ways, and (b) serve as an independent supervisory body for the whole program. It is very desirable that the base funding for the Science Centers program be provided by the National Science Foundation since, in this and other ways, it is important that these centers have strong science discipline character.

b. We believe that there should be contributory financial support to the Regional Centers from the states. The financial role of school districts and institutions of higher education will be manifest in their partial support of teachers and faculty members assigned to the Centers for limited periods. The contributions of industry to this program in the national interest can be the most varied of all, ranging from direct financial contributions, through the donation of other kinds of material resources, to the temporary loan of skilled and interested professionals.

The program of each regional center should be sensitive to the general and specific needs of the member states as well as to defined national objectives in science education K-12. The ten or so centers should be only lightly tied together, but there should be free flow between them of expertise and developed products. A broad spectrum of science disciplines should be represented at each center, such diversity being necessary to meet the needs of both elementary and secondary schools. Cognitive science and information technology specialists must be part of the staffing of every center. Center programs will have important currency and vitality if both academic and industrial scientists are included in the rotating staff.

The centers should be located optimally with respect to significant factors such as: convenience of access to teachers for short-term assignments; strong academic support by a host institution (which should have well-established and high quality programs in all of the basic sciences); availability of laboratory, other educational, and visitor residence facilities (though some dedicated to the centers would be expected to be constructed under the program as it matured).

Teachers will not become involved in the programs of the Regional Science Centers if they are disadvantaged financially by such participation. Even highly compensated health professionals pursue required continuing education only when suitable incentives are provided; greater self-sacrifice should not be expected of the nation's poorly compensated and much maligned teachers. Federal support, possibly tied to state and school district support, should be made available for summer salaries of teachers participating in institutes or workshops, for sabbatical leave salaries of teachers serving as rotating staff members, for university and college faculty directing and carrying out staff functions, etc. We recommend that state and local teacher certification be dependent on regular participation in educational activities such as the workshops and institutes which would be programmed by regional centers, and other subject matter-oriented education.

Our view of the importance of new curricular and instructional materials is parallel to that of The National Commission on Excellence in Education:

> "Textbooks and other tools of learning and teaching should be upgraded and updated to assure more rigorous content. We call upon university scientists, scholars, and members of professional societies, in collaboration with master teachers, to help in this task, as they did in the post-Sputnik era. They should assist willing publishers in developing the products or publish their own alternatives where there are persistent inadequacies."

Although teacher participation in Center programs should over time, improve school science instruction, the creation and dissemination of curriculum and instructional materials developed or selected through Center activities would provide immediate assistance to a large number of school districts. Federal budgeting for the regional centers should include substantial sums for both development and dissemination of materials.

It should be noted that several regional science centers were established under a former NSF program. Their experience should permit avoidance of many pitfalls in the development of the centers proposed here.

E6: ACS ACTIVITIES IN PRE-HIGH SCHOOL CHEMISTRY EDUCATION

Recommendation: Expansion of ACS activities in the area of pre-high school chemistry education.

The American Chemical Society recently has established an Office of High School Chemistry in its (staff) Education Division to implement a wide variety of programs in support of high school chemistry teaching, including that intended for the general (nonscience oriented) student. In this and preceding sections of this Report, we have identified and proposed a number of new responsibilities that should be undertaken by the Society. Other responsibilities for the Society are implied by the recommendations of the 1982 ACS Invitational Education Workshop on *Chemistry in* *the Kindergarten-through-Ninth-Grade Curricula*, and by the recommendations in other recent national reports, especially that of The National Commission on Excellence in Education. It is, therefore, appropriate and timely that an ACS staff function be created to serve pre-high school chemistry education.

E8. The American Chemical Society should expand its activities in the area of pre-high school chemistry education to implement the recommendations of recent ACS studies, those from other national reports, and other elements of ACS science education policy as they apply to the pre-high school years.

a. Initially, this assignment might be given to the present Office of High School Chemistry, making it, in effect, an office with responsibilities covering the whole of precollege education. Experience should determine the desirability of and need for a separate office for the pre-high school activities of the Society.

b. Among the specific responsibilities of the expanded staff function should be the stimulation of increased interaction between elementary school teachers with a specialty in science and both academic and industrial scientists. It should also sponsor the preparation of teaching modules for use at various grade levels K-9, consistent with the curriculum recommendations of the National Council and presenting chemistry from a sound and balanced perspective appropriate to its centrality among the sciences.

Recommendations on HIGH SCHOOL CHEMISTRY AND SCIENCE

H1 A Five-Year Plan to Improve Chemistry Education in the High Schools
H2 Raise Teacher Certification Standards: Improve Qualifications
H3 Science Requirement for High School Graduation
H4 High School Chemistry Courses
H5 The Laboratory Component of High School Chemistry

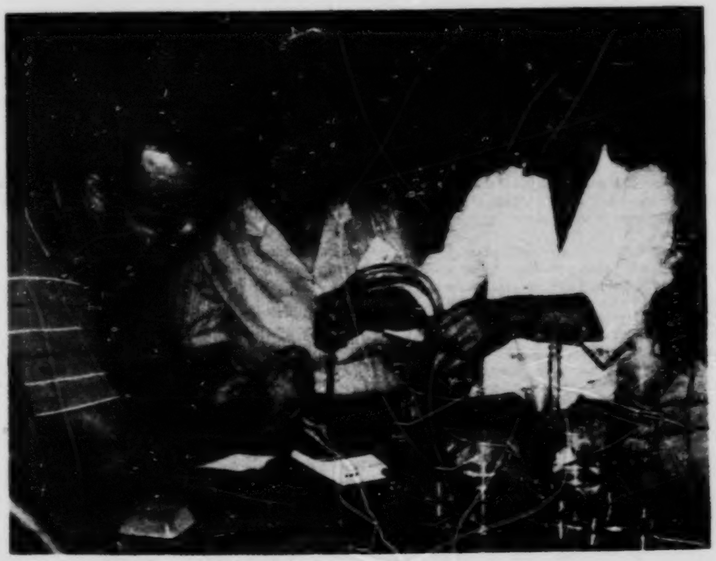

Photo: National Science Teachers Association

Colleges and universities should offer at convenient times and in accessible locations those formal courses that would permit numbers of individuals in their service areas to complete certification requirements, pursue advanced degrees, and in other ways increase their potential as knowledgable and qualified high school teachers.

H1: A FIVE-YEAR PLAN TO IMPROVE CHEMISTRY EDUCATION IN THE HIGH SCHOOLS

Recommendation: Creation of an ACS 5-year plan to improve chemistry education nationwide in the high schools.

No level of science education has attracted more numerous expressions of concern and more varied suggestions for remedy during the work of this Task Force than the high school level. High school is where the science awareness and science literacy of students can be powerfully advanced by the simultaneous application to subject matter and issue-oriented material of all the learning skills developed to that time. High school is where serious interests develop, the general areas in which careers might be pursued are explored, and where tentative choices are made. High school is where those with a particular orientation can be exposed to work supporting that orientation—to study that demands of them some rigor, intensity, and sophistication of effort, and rewards them with achievement and senses of accomplishment and identification.

At present, science education in the high schools taken as a group reflects neither the personal significance nor the national importance of the subject.

The shortage of properly qualified teachers is well documented; many now in service appear to have had training that is at best marginal for the demands of current science instruction; few are compensated at levels appropriate to the importance of their efforts or competitive with other and increasingly attractive opportunities.

There are only inadequate resources and programs available for the refreshment and upgrading of the background of those effective and interested science teachers who elect to remain in the high schools; indeed, the national effort in support of such programs has waned just as the national dependence on its results has waxed.

There are excellent programs in chemistry that work for the most strongly motivated students, including many who will elect a career in science, but these fine programs appear to be less effective for those with nascent potential in science. The less challenging courses that are generally available fail to motivate high ability students sufficiently to make even a tentative choice of one of the chemical sciences as a career. Further, students without career interests in science do not, in general, receive instruction in chemistry adequate for discriminating and intelligent citizenship.

Chemistry and other laboratory sciences are often taught as if they were done and over with, instead of being presented as open-ended and experimental fields (computer simulation is especially pernicious because it does implant the notion that somebody already knows all the answers); opportunities for students to study chemical change through their own efforts in properly equipped instructional laboratories are decreasing.

H1. The American Chemical Society's Division of Chemical Education and the Society Committee on Education, in consultation with appropriate other bodies and individuals, especially high school chemistry teachers, should create a 5-year plan for using available and expected resources to improve chemistry education nationwide in the high schools. This plan should provide a priority listing of goals, programs, and activities for pursuit during five years by the education components of the Society, and should relate to likely and desirable programs supported by the United States Government, by state governments, and by private industry.

The most critical areas in need of attention are the quality of the teacher, the quality of the content of chemistry courses, and the quality of the experience afforded to all students.

a. We recommend also, that the American Chemical Society's Committee on Education, in concert with selected representatives of the Society's governance and operating structure, develop machinery that will enable chemists to influence appropriately and significantly the planning, development, and implementation of the forthcoming changes in science education, especially at the high school level, that will follow upon the recommendations of The National Commission on Excellence in Education (which reported in April 1983) and The National Science Board Commission on Precollege Education in Mathematics, Science, and Technology (which reported in September 1983).

b. While it is unlikely that the Society could, at this time, undertake high school chemistry program approval, it should do more to add force to its recommendations for teacher preparation and continuing education. Education committees of ACS local sections might be willing to assist high schools in their areas and work for public support of better chemistry education in their communities. The most powerful force for educational improvement is an informed and aroused constituency.

H2: RAISE TEACHER CERTIFICATION STANDARDS: IMPROVE QUALIFICATIONS

Recommendation: A national effort to raise teacher certification standards in science and mathematics and to secure adherence to such standards.

The majority of secondary school teachers certified to teach chemistry are competent to teach basic chemical principles and to present the existing curriculum effectively and with understanding. But even such teachers need ways of maintaining and advancing their professional skills beyond those that are conveniently available at this time. Unfortunately, the vast majority of secondary school students are not being taught chemistry by certificated teachers of chemistry – they are being taught by persons who have minimal background in the subject and little if any qualification to maintain and advance their working familiarity with it, however acquired. As there is a critical mass in explosions, so is there a critical amount of background necessary before teachers at any level can be self-sustaining in updating their skills in and refreshing their knowledge of any subject. Most persons who teach chemistry in the secondary schools today do not have that critical amount of background in chemistry.

According to recent surveys and samplings, over half of newly appointed science teachers have qualifications less than the often low existing state standards; among teachers whose class assignments are at least half in science courses, 32 percent majored in a science; and, the number of students graduating each year with majors in science *instruction* (which is short of the optimal preparation for high school science teaching) is less than the need in 40 of the 50 states.

It is clear that standards for certification of teachers to teach science must be increased, that present teachers must be assisted to maintain and improve their science-related professional skills, and that present and future teachers must be afforded the status and compensation which are among the most powerful incentives to keeping good teachers in good schools instead of losing them to satisfying employment outside education. The present mismatch between necessary and actual qualifications and numbers of high school teachers of science, especially chemistry, must no longer be tolerated.

H2: The National Council (N1), the American Chemical Society, other science societies, and the appropriate agencies of the United States Government should work more closely and more forcefully with state education agencies: (a) to raise teacher certification standards in science and mathematics; and (b) to set limits on administrative use of emergency or temporary certification (which tends to continue indefinitely) of persons underqualified to offer sound science instruction. To the former end, the American Chemical Society should review and update its 1977 "Guidelines and Recommendations for the Preparation and Continuing Education of Secondary School Teachers of Chemistry"; to the latter, the Society should increase its own efforts to bring into high school teaching professional scientists who are qualified in science education.

No matter what improvements in the high school science curriculum are devised and implemented to increase the science awareness and literacy of students, or to furnish a basis for their serious consideration of science-related careers, it is the high school science teacher who will present that curriculum and whose qualifications will, in large part, determine its success. In earlier sections of this report, the Task Force urged immediate action of two fronts to increase the opportunities for updating and upgrading the science-related professional competencies of high school teachers of science, including chemistry: in Section A1, the whole panoply of programs of teacher improvement funded by the National Science Foundation; in Section E5, Regional Science Centers, which have a role to play in the improvement of secondary school science instruction at least as significant as their role in elementary school science education. An even greater variety of opportunities needs to be made available, because of the diversity of the personal and professional situations of individual high school teachers.

a. Sound preparation for teaching chemistry in high school is similar to the content of the undergraduate liberal arts major in chemistry (30–35 semester hours of chemistry, 10–15 of physics, 10–15 of mathematics, and substantial work in English and a foreign language) plus professional work in preparation for teaching in general and for teaching laboratory-centered science in particular (12–18 hours).

b. Workshops should be offered for college or other acceptable credit that would allow high school chemistry teachers, through evening, Saturday, or summer attendance, to become more knowledgeable in the field of chemistry. Updating and strengthening of information on basic concepts, applications of chemistry, and chemical facts are especially useful and needed.

c. Colleges and universities should offer at convenient times and in accessible locations those formal courses that would permit numbers of individuals in their service areas to complete certification requirements, pursue advanced degrees, and in other ways increase their potential as knowledgeable and qualified high school chemistry teachers. Similar programs, especially in the area of professional education, should be made available to professional scientists who wish, upon retirement or at other times, to assist the national effort to improve high school science instruction by becoming qualified high school teachers themselves, full- or part-time. (An example of such a program is that in St. Louis sponsored jointly by the Monsanto Company and Washington University.)

d. We recommend that the National Council and its component scientific and engineering societies mount programs of public information in support of the changes in conditions of employment of high school teachers necessary to attract qualified persons to such teaching and to retain them there. These changes include: compensation competitive with alternative careers; scholarship, tax-preference, and other financial inducements to enter and remain in teaching; salary schedule advancement and tuition assistance for subject matter continuing education in addition to that derived from methods education and longevity; released time for the special preparations that are necessary for the safe and effective teaching of science at the high school level; and the allocations of both personal assistance and material resources to the laboratory component of instruction required for its effectiveness and safety.

e. Because optimally-prepared high school chemistry teachers who keep abreast of their science are attractive to other employers, it would be in the national interest for such employers to work with school districts and individual teachers to develop programs that share these scarce persons between academic and private sector employment. Summer positions in industrial laboratories have long been available to qualified high school teachers; we commend such arrangements and urge their substantial increase and expansion. Industry can do much in other ways, by supporting special equipment needs, sponsoring awards for both student and teacher excellence, and by making its interested and qualified personnel available to the nation's schools. (It is gratifying that Congress is now considering several pieces of legislation that would support such industry involvement in the improvement of science education.)

f. The overall effectiveness of education in science would be improved significantly by closer interactions between high school and college faculties. The Task Force recommends strongly that individual colleges and universities assume leadership in developing opportunities for such interactions. In the field of chemistry, the local sections (membership) of the American Chemical Society could provide interested and qualified persons to assist these efforts.

H3: SCIENCE REQUIREMENT FOR HIGH SCHOOL GRADUATION

Recommendation:* *Adoption of a national minimum standard that 3 years of science taught with laboratory and 3 years of mathematics be required for graduation from high school.

For twenty years or more, academic requirements for graduation from high school have been steadily eroded. There are many reasons for this trend, and the forms taken by the erosion are similarly diverse. Science has been an important aspect of the national life for over a century, and its importance continues to increase. It is in the high school that society has its last opportunity to assure that all its future adult citizens have a sound basis in science for citizenship. It is in the high school that students become aware of the existence of the enormous number of career opportunities that depend to some substantial degree on the acquisition of foundational knowledge of disciplinary science. And, it is in high school where students can first be shown, through application of the learning skills already acquired, something of the structure and detail of the great disciplinary areas, science foremost among them.

The address of some of these objectives for all students and all of these objectives for some students requires real contact with at least the three great central sciences—biology, chemistry, and physics. We do not argue for any particular approach to any of them, for "equal time," or for any one sequence. We do argue that all students should be exposed to all three of them and that there should be hands-on laboratory experience in all three of them.

H3. The National Council (N1) supported by the American Chemical Society and other science societies should work closely and forcefully with state school boards and other education agencies toward a national minimum standard that 3 years of mathematics and 3 years of science taught with laboratory be required for graduation from high school, the latter including substantial amounts of biology, chemistry, and physics.

a. This proposed standard is consistent with Recommendation A (curriculum content) of The National Commission on Excellence in Education. We urge immediate effort towards its adoption.

b. Parallel to the need for substantial science in the high school curriculum is that for improved guidance of students by high school counselors as to the career opportunities related to that science instruction. The science societies have an obligation to improve and extend their services to high school counselors through updating of their present information materials, provision for counselor workshops, and other means of establishing and maintaining effective communication between the present and potential workers in science-related occupations.

c. We recommend also that high school guidance counseling be so conducted that students are made aware early that every career preparation of lasting value requires a sequence of commitments over the high school years and beyond. High school curricula should be broad and general so that options are not inadvertently foreclosed. This is an especially serious problem in technical areas because the ability of colleges and universities to remedy omissions from the high school years is decreasing rapidly.

H4: HIGH SCHOOL CHEMISTRY COURSES

Recommendation: Study of changes necessary to improve the high school chemistry curriculum.

Earlier we noted that the present high school science curriculum appears to work for the most strongly motivated students, but not for those whose interest in science is nascent or quiescent. Part of the problem seems to lie in the apparent necessity for many high schools to offer just one chemistry course. Especially if some significant exposure to chemistry, including laboratory, is to be required of all students, some accommodation must be made to the fact that a majority may not pursue more advanced study of chemistry.

At least two different types of high school chemistry courses could be developed and offered. One would be a course intended to convey to the nonscience student some of the structure and detail of modern chemistry, with emphases on the chemistry that is involved in the phenomena of everyday life; how chemistry is similar to other sciences, related to them, and differs from them; what national problems and opportunities have a significant chemistry component. The other would be a truly modern course that would give an introduction to chemistry to those students who are likely to make career choices that will require additional formal work in the science; it would cover the same general topics as the course for nonscience students, but would emphasize chemical fact, the ways of establishing chemical fact, the ways of organizing chemical fact, and would introduce the students to the different ways of thinking about chemical knowledge.

Both of these courses require attention from the chemical profession itself, and should not be developed by high school teachers only, college and university teachers only, or even by a combination of just these two groups.

We recognize that our beliefs about chemistry courses may not have the universal serviceability we hope for them. Therefore:

H4. The National Council (N1) should guide a study by the American Chemical Society, with appropriate contributions from societies centered in sister disciplines, of the high school chemistry curriculum and recommend such changes as are found necessary to improve the effectiveness and utility of that curriculum. Resources should be developed to encourage high schools with sufficient enrollment to offer two (or more) different chemistry courses, to meet the needs of different major fractions of their students.

a. We encourage experimentation with ways of incorporating chemistry into the description of phenomena widely throughout the entire school curriculum so that, as students approach upper-level courses, they have sufficient background to make intelligent choices among the different kinds of chemistry courses available to them, and that those choices are not foreclosed.

b. We discourage as strongly as possible developments in high school chemistry courses which make them into descriptive, elementary, or warm-up versions of the first year college chemistry courses. Introductory college chemistry has its own problems and the widespread emulation of its content in high school courses, and, worse, in texts intended for them, is a disservice to many students at both levels. Perhaps the most salutary result of closer interactions between college and high school chemistry faculty members would be spreading agreement on the division of the tasks we share.

c. High school chemistry courses should have the characteristics recommended by The National Commission on Excellence in Education: "The teaching of science in high school should provide graduates with an introduction to: (a) the concepts, laws, and processes of the . . . sciences; (b) the methods of scientific inquiry and reasoning; (c) the application of scientific knowledge to everyday life; and (d) the social and environmental implications of scientific and technological development."

H5: THE LABORATORY COMPONENT OF HIGH SCHOOL CHEMISTRY

Recommendation: Adoption of a guideline that at least 30 percent of class time be devoted to laboratory exercises in the high school chemistry curriculum.

> "While reading a textbook of chemistry, I came upon the statement, 'nitric acid acts upon copper' . . . and I determined to see what this meant . . . Having located some nitric acid, . . . I had only to learn what the words 'act upon' meant . . . In the interest of knowledge I was even willing to sacrifice one of the few copper cents then in my possession. I put one of them on the table; opened the bottle marked 'nitric acid'; poured some of the liquid on the copper; and prepared to make an observation. But what was this wonderful thing which I beheld? The cent had already changed, and it was no small change either. A greenish blue liquid formed and fumed over the cent on the table. The air became colored dark red . . . How should I stop this? I tried by picking the cent up and throwing it out the window . . . I learned another fact; nitric acid acts upon fingers. The pain led to another unpremeditated experiment. I drew my fingers across my trousers and discovered nitric acid acts upon trousers . . . That was the most impressive experiment . . . I have ever performed. I tell of it even now with interest. It was a revelation to me. Plainly the only way to learn about such remarkable kinds of action is to see the results, to experiment, to work in a laboratory." (Ira Remsen (1846–1927), educator, chemist)

Chemistry is a laboratory science. But, as teacher qualifications have declined and costs have increased, the amount of time devoted to student laboratory exercises in high school chemistry has decreased steadily. In many schools, demonstrations by the teacher (always an important and effective mode of instruction) are the only opportunities afforded students to observe the phenomena of chemistry. Chemistry is an experimental science. Its great attraction as intellectual experience and training is that even a beginner can carry out experiments that yield observations to be interpreted and explained. With even a little experience, a student can make measurements of chemical phenomena and learn the techniques for converting quantitative data into testable hypotheses.

Recently, computer simulation of laboratory exercises has seemed to afford relief from the costs and logistical problems associated with the maintenance and conduct of student laboratory work, particularly in high schools. The novelty and attractiveness of some computer simulations cannot be doubted, but neither can their inappropriateness as a *substitute* for hands-on student laboratory experience. The computer does have a place in the chemical laboratory: as a data processor, to permit unusual and effective display of the results of student observations, as a tutor in methods and procedures, and as evaluator of learning and understanding; but computer simulation is not a desirable or effective substitute for direct experience with the behavior of chemical systems.

H5. The Task Force recommends that any American Chemical Society guideline for the high school chemistry curriculum provide that at least 30 percent of class time be devoted to student laboratory exercises. The Society's education bodies should study the costs as well as the content of laboratory instruction and recommend ways in which effectiveness can be maintained when resources are limited.

a. It is possible that some of the rapid increase in high school laboratory costs are the result of imitation there of the kinds of exercises done in the first year general chemistry laboratories in colleges and universities. Colleges and universities are under the same kinds of fiscal pressures experienced by school districts; neither should do the work of the other. Academic chemists should join with interested chemists from industry to develop laboratory exercises for both school and college courses that are faithful to the content of modern chemistry without requiring its sophisticated instrumentation.

Surveys which have included students show that they are enthusiastic about laboratory work—in all high school science courses, not just chemistry. It is important that constructive educational use be made of the enthusiasm, especially since this finding is independent of whether the student is self-classified as "science-oriented" or "general."

Recommendations on TWO-YEAR COLLEGE CHEMISTRY AND CHEMICAL TECHNOLOGY

T1 American Chemical Society Guidelines for Chemistry in the Two-Year Colleges
T2 Outreach and Consultation in Aid of Instructional Improvement
T3 American Chemical Society Approval of Chemical Technology Programs
T4 ACS Approval of Other Two-Year College Programs in Chemistry

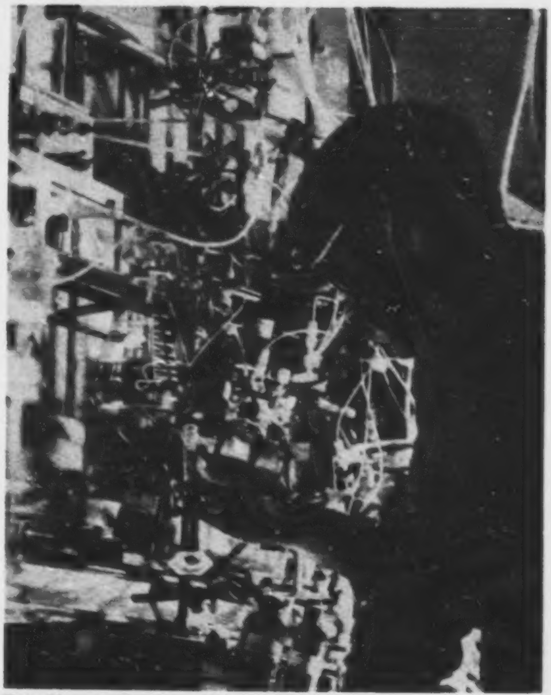

Photo: Monsanto Company

The American two-year college . . . must meet the high standards of those who accept its output . . .

T1: AMERICAN CHEMICAL SOCIETY GUIDELINES FOR CHEMISTRY IN THE TWO-YEAR COLLEGES

Recommendation: Revision of the ACS 1970 "Guidelines for Chemistry in the Two-Year Colleges"

The American two-year college has the most diverse and perhaps the most demanding constituencies of any of the kinds of educational institutions flourishing in the United States today. In every dimension it is complex and broad. It is called upon to prepare students for specific occupations and for transfer to four-year institutions; it must meet the high standards of those who accept its output while repairing the effects of too low standards employed by those who produce its input; it enjoys both multiple financial support and multiple bureaucratic oversight; and, in addition, it must meet the self-defined educational needs of a substantial fraction of the adult population.

The implications of these characteristics for two-year college instruction in chemistry have been examined several times. Notable among such studies were the 1969 *Conference on Science in the Two-Year College* (sponsored by several of the then extant science commissions) and the 1980 review (supported by the National Science Foundation) by the Center for the Study of Community Colleges resulting in the report "*Science Education in Two-Year Colleges: Chemistry.*" However, there is little evidence that their recommendations, which were published widely, were utilized by such colleges or their parent systems to improve or even to maintain the quality of chemistry or other science instruction programs.

The American Chemical Society, after a thorough study, published in 1970 a set of *Guidelines for Chemistry in the Two-Year Colleges*, somewhat analogous to that for undergraduate professional education in chemistry published by the Society's Committee on Professional Training. Because there was no implementation monitoring or compliance review mechanism established, analogous to the Committee's approval program for undergraduate pre-professional curricula, the 1970 Guidelines have not had the beneficial effects expected of them.

Recommendation T1 and others that follow recognize the need to update the 1970 *Guidelines* and, by developing an action plan for their utilization, make them an effective instrument for instructional improvement.

T1. The American Chemical Society Committee on Education should undertake to revise the 1970 "Guidelines for Chemistry in the Two-Year Colleges" to reflect the diversity of chemistry education responsibilities that have become the norm for individual two-year colleges in the past 15 years.

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a. This revision should reflect the comprehensive nature of two-year college chemistry programs rather than be limited to the transfer programs for intended chemistry majors. Further, the revision should address two major issues which have special intensity in the two-year colleges: standards for student performance, and adequate funding requirements.

b. If there is to be acceptance and utilization of the revised Guidelines, they should be accompanied by suggestions of the appropriate audiences to receive them and effective methods for their implementation at the departmental, institutional, and system levels.

T2: OUTREACH AND CONSULTATION IN AID OF INSTRUCTIONAL IMPROVEMENT

Recommendation: Development by ACS of an outreach and consultation program to assist improvement of chemistry programs in two-year colleges.

Because of their internal diversity and complexity, two-year colleges present difficult management problems. Few of their top administrators have science or engineering backgrounds. "Guidelines," and other forms of "approval" or "accreditation" standards, justifiably can be viewed with suspicion. The American Chemical Society has a long and distinguished record of non-coercive encouragement of and support for the maintenance and improvement of quality chemistry education at the undergraduate level. Since the two-year colleges are an important fraction of the national apparatus for undergraduate education, the Society should take steps to bring to them the same kind of outreach and consultation in aid of instructional improvement that has been available to institutions awarding the baccalaureate degree.

T2. The American Chemical Society should develop an outreach and consultation program that would make the expertise of the Society staff and membership more effectively available to two-year college administrators whose institutions are engaged in substantial efforts to improve the quality of their chemistry programs.

a. In support of such activities, it would be desirable for the National Council and its component discipline-related associations to undertake studies of the special costs needed to maintain science instructional programs of the necessary quality, so that such information is available to administrators and consultants. Further, these studies might well give attention to the development of new approaches to funding these special costs. Local industry, a major employer of the occupationally-educated two-year college graduate, has been a generous supplier of nearly state-of-the-art equipment to such educational programs. These efforts need to be expanded, and their analogue for academic transfer program instrumentation and equipment needs must be developed.

T3: AMERICAN CHEMICAL SOCIETY APPROVAL OF CHEMICAL TECHNOLOGY PROGRAMS

Recommendation: Establishment of an ACS approval service for Chemical Technology programs.

Chemistry programs of two-year colleges are not among those eligible for the review and approval system for undergraduate pre-professional instruction carried out by the American Chemical Society's Committee on Professional Training. The review of such programs by regional accrediting bodies or by state two-year college boards is usually cursory, may be minimal, is often carried out by persons who have neither science nor chemistry background, and is not done with respect to guidelines that have been accepted or generated by the chemistry education community.

We believe that many benefits would flow from initiation by the American Chemical Society of a program approval activity directed to the needs of the two-year colleges. Institutions should have the opportunity, after careful internal self-evaluation, for external review of program, progress, and planning, by qualified chemistry educators working from guidelines developed and accepted by the chemistry education community.

Because of the great diversity of curricular needs addressed by two-year colleges, it is important that such a program approval activity develop gradually, covering first those curricula that are well defined, then those less highly structured.

T3. When the Revised Guidelines (T1) have been published and the outreach and consultation program (T2) is functioning, the American Chemical Society should undertake to certify/approve Chemical Technology programs in two-year colleges at the request of such institutions.

a. Like the present program of the ACS Committee on Professional Training, this activity in support of quality chemistry education in the two-year colleges should be voluntary on the part of the institutions and based on curriculum guidelines and review procedures that have been developed carefully and sensitively by highly qualified chemistry educators working closely with representatives of a cross-section of employers of chemical technicians.

b. A useful first step could be to offer the opportunity to two-year colleges for external review of their own self-evaluations conducted in light of the published *Guidelines*.

T4: AMERICAN CHEMICAL SOCIETY APPROVAL OF OTHER TWO-YEAR COLLEGE PROGRAMS IN CHEMISTRY

Recommendation: Development of an ACS approval service for college transfer and other two-year college chemistry programs at the request of such institutions.

Chemical Technology programs are relatively few in number and there is some agreement as to their level and content, though all of which we are aware interact flexibly with local and regional employers to assure a reasonable match between specialized components of the programs and the requirements of changing employment opportunities. The college transfer programs offered by two-year colleges are much more numerous and are influenced in much more detail by the necessity to maintain reasonable correspondence between their content and that of related programs of instruction in the colleges and universities to which students transfer at the end of one or two years. When students may transfer to any of several institutions, as is almost always the case, the demands made upon the ingenuity and skill of two-year college faculties are considerable.

Because of this pluralism and variety, many have discouraged the Society from extending to the two-year colleges the kind of direction and assistance implied for four-year institutions by the *Guidelines* of the ACS Committee on Professional Training. But, because two-year colleges are a part of the higher education system that eventually graduates baccalaureate chemists, we believe that that extension should occur—and on the same basis: at the invitation of the institution, when it has determined that it wishes to be rated against the appropriate guidelines.

T4. When Recommendations T1, T2, and T3 have been implemented, the American Chemical Society should undertake to certify/approve college transfer and other chemistry programs in two-year colleges at the request of such institutions.

Recommendations on UNIVERSITY AND COLLEGE CHEMISTRY AND SCIENCE

U1 College Admission Requirement in Science
U2 College Graduation Requirement in Science
U3 Chemistry Courses for Nonscientists
U4 Reduction of Cultural Duality: Interdisciplinary Integration
U5 Laboratory Instruction in Foundational Chemistry Courses
U6 Chemistry Courses for Undergraduate Nonchemists
U7 Chemistry Modules for Professional Curricula
U8 Laboratory Experience in the Chemistry Curriculum
U9 The Approved Curriculum in Chemistry
U10 Characterization of Career Opportunities in Chemistry
U11 Mission and Structure of the ACS Committee on Professional Training
U12 Information Management

Photo: University of Wisconsin, Madison

[. . . a chemistry course] should represent a significant intellectual challenge; it should present substantial information on the properties and reactions of real materials . . .

U1, U2: COLLEGE ADMISSION AND GRADUATION REQUIREMENTS IN SCIENCE

Recommendation: ***National effort to attain acceptance of a requirement for admission to colleges and universities of at least 3 years of laboratory science and 3 years of mathematics taken in grades 9–12.***

Recommendation: ***National effort to assure that the laboratory science requirement for any baccalaureate degree is at least 10 percent of the undergraduate credit that must be earned by the student.***

The thoughtless early specialization and strong vocationalism that now characterize both secondary and collegiate education in the United States have eroded many aspects of liberal education and deprive students of its life-long benefits. We are sympathetic to those who propose restoration to the school curriculum of real contact with more than excerpts from the great literature of the world (and not just in our own language), addition to it of significant exploration of the fine arts, and elimination from it of needless repetition of self-centering concerns; and to those who propose the corollary changes in the degree programs of colleges and universities. Further, we believe that both school and college curricula need substantial strengthening with respect to other liberal and liberating arts—the sciences and mathematics.

In a preceding section devoted to the high school, (Recommendations H1–H5) this Task Force has urged strengthening of offerings and requirements for high school graduation. At the college level, too, there is presently a lack of desirable emphasis on foundational work in technical and scientific subjects. A survey by the National Research Council indicated that an average of 7 percent of undergraduate course work was required to be devoted to the natural sciences in 1980; compared with over 9 percent in 1967. Both high school offerings and college requirements drifted downward in this period, the former more rapidly than the latter.

This trend must be reversed if graduates of schools and colleges are to be prepared for the world that actually exists about them, a world that is increasingly dependent upon and reflective of science and technical endeavor. Many college graduates lack the background to deal with the technical aspects of some of the complex and major issues confronting contemporary society. Issues such as disposal of toxic wastes, environmental quality, occupational safety, nuclear power, and manipulation of genetic material, involve decisions by government. Ultimately, the government is the people and they should be both aware and informed. Most sciences, chemistry among them, relate to these issues. Even more important however, is the study of science as a powerful method of inquiry into the nature of the world about us.

A general increase in science requirements for college entrance would have a very desirable positive effect on secondary school curricula and graduation requirements. A general increase in distribution requirements for all college students would enlarge the science knowledge of a still growing, better educated group of the population, providing them with genuine understanding of the nature and content of science and increasing their capacity for discernment, critical evaluation, and sound judgement where science is a factor. Language and literature may be under pressure as major components of liberal education, but science and mathematics have yet to be accorded the recognition and study appropriate to their significance in the contemporary lives of society and the mind.

U1. The National Council (N1) in concert with the American Chemical Society and other science and engineering societies should work with national and state educational agencies, educational consortia and accrediting bodies, and precenter colleges and universities to attain acceptance nationwide of a requirement for admission to all colleges and universities of at least three years of laboratory science and three years of mathematics taken in grades 9–12.

a. We recommend that this science requirement be increased gradually to four full years of secondary school (grades 7–12) laboratory science, to include both chemistry and physics. We recommend that the mathematics requirement be increased gradually to four full years of secondary school mathematics, to include two full years of algebra. And, increases in content and achievement are the objectives, not just increase in time spent. The continuing downward drift in the fraction of credit in science offered in satisfaction of requirements for baccalaureate degrees is not in the national interest.

U2. The American Association for the Advancement of Science in concert with the American Chemical Society and other science and engineering societies should work with national and state education agencies, educational consortia and procentor colleges and universities to assure that the amount of laboratory science required for any baccalaureate degree is at least 10 percent of the undergraduate credit which must be earned by the student.

U3: CHEMISTRY COURSES FOR NONSCIENTISTS

Recommendation: Establishment of guidelines to the appropriate balance in college-level chemistry coures for nonscience majors among the fundamental principles of chemistry, applications of chemistry, and the place and role of the chemical sciences in contemporary society.

It would be an empty gesture to increase college graduation requirements in science without taking steps to assure that sound, informative, interesting, and useful courses exist to be applied to the requirements. Generally, introductory courses intended for science students or, worse, for majors in the field of the course, fail to meet the needs of majors in nonscience fields. Such courses assume both more background and more interest than the general student should be expected to bring to them; they tend to be narrow and detailed, strongly-focussed, and swiftly-paced; they discuss the trees and not the forest.

The decade ending in 1977 yielded almost 150 reports in the *Journal of Chemical Education* alone on curriculum and course developments in chemistry intended to meet the needs of the general student; many additional reports have appeared since that time. Some of the special courses described in these reports are elementary, non-mathematical versions of the standard introductory courses offered to science-oriented students; some have a strong "applied" or "environmental" orientation; and some focus narrowly on key topics such as forensic science, popular drugs, kitchen chemistry, or art and antiquities.

Critics of the special courses have argued that many of them fail what ought to be their central objective, to illustrate the nature of science and scientific thought, because of overemphasis on facts and underemphasis on process and methods. Others are found wanting because they avoid mathematics and abstraction, in spite of the fact that it is virtually impossible to gain admission to a college or university in the United States without a year of algebra and a year of geometry in one's secondary school program.

The Task Force applauds the interest and energy which have gone into these attempts to meet the needs of the general college student. It would be a mistake to strive for a high degree of uniformity in such course offerings simply because the national interest, as well as personal interests, were served by increased understanding of the sciences. However, we do argue that a chemistry course for non scientists ought to have certain hallmarks: it should represent a significant intellectual challenge; it should present substantial information on the properties and reactions of real materials, particularly substances that students might be expected to encounter in the ordinary course of affairs; it should show how models and hypotheses are used to organize and interpret such information, leading to the establishment of principles and "laws" of chemical behavior; it should emphasize the experimental, tentative, open-ended, and falsifiable nature of chemical knowledge, and provide examples of coherence, logical extrapolation, ambiguity, and irrelevance; and it should include material on both the historical origins of the discipline and its present societal significance. It should not be trivial, condescending, patronizing, or apologetic, nor should it be at high dilution or without rigor. In the words of V.V. Raman:

> ". . . (it) should be taught not simply as a body of useful knowledge clothed in technical vocabulary but as a mode of inquiry into the nature of the perceived world, as an intellectual framework to guide us in the adoption of tentative interpretations of what is observed, and as a world view that is not ultimate truth but is applicable only in the context of a given set of available facts . . . (It) should be taught because of the value system it fosters, because of its criteria for the acceptance of points of view as valid propositions—not because of its potential exploitable results, or even for its beautiful and powerful theories."

U3. An American Chemical Society Task Force on Chemistry Education for Nonscientists, which might be the body described in N4 or an ad hoc sub-unit of the Society Committee on Education, should consider the general and diverse aims of college-level courses taught for nonscience majors and establish broad guidelines to the appropriate balance in such courses among the fundamental principles of chemistry, the methodology and philosophy of the disciplines, applications of chemistry, and the place and role of the chemical sciences in contemporary society.

a. After guidelines are available, the Society, with assistance of other funding sources, such as the National Science Foundation and private educational foundations, should sponsor workshops for the creation and improvement of chemistry courses for nonscience majors (whose needs might be met more effectively by offering them sophisticated courses as seniors instead of introductory courses when they are freshmen).

b. In both the pre- and post-guideline periods, the Education Division of the American Chemical Society, or a unit like the Institute for Chemical Education (University of Wisconsin-Madison), could assist the improvement of such course offerings by establishing a clearinghouse for the exchange of syllabi, instructional modules, and other information.

U4: REDUCTION OF CULTURAL DUALITY; INTERDISCIPLINARY INTEGRATION

Recommendation:** **Development of workshops and other activities to increase interaction among teachers of the natural sciences and engineering, the arts, humanities, and the social sciences.

Improvement of the science literacy of students, especially at the college level, may depend on the simultaneous and *joint* improvement of other literacies. Science faculty in general and those in chemistry in particular often insulate themselves from the nonscience academic community, just as, in our view, the nonscience academic community is insulated from us. Unless there is better integration of science and chemistry with the totality of the intellectual enterprise, renewed emphasis on science awareness and literacy could simply widen the gap between the "two cultures."

The academic year does not provide enough opportunity for those who teach in very different disciplines to exchange viewpoints on issues of common concern with an eye to the development of integrated multidisciplinary instruction centered on them. Natural scientists, engineers, humanists, social scientists, and those in the arts all have contributions to make to our understanding of matters such as: the interaction between science and literature; the impact of technical activity on the human and physical environments; ethical consequences of the application to human beings of the findings of molecular biology and genetic chemistry; the philosophical implications of modern physical theory; uniqueness in the universe; profits and prophets; preservation of the past; and other similar topics, without limit.

Some of the Chautauqua-type short courses sponsored by the National Science Foundation have brought scientists and nonscientists together to learn about progress in areas such as the history of science, research in cognition, and the social consequences of the computer revolution—all of which bridge the gap between the two cultures. We applaud this program and urge its expansion. But more extensive activities of a similar orientation are necessary to accelerate this integration.

U4. The National Council and the supporting societies mentioned in U1 should promote the development and establishment of a program of summer workshops and other suitable mechanisms to bring together teachers of chemistry, other natural sciences, engineering, the arts, humanities, and the social sciences, to study issues of common societal and intellectual concern so that the fruits of such study may be applied directly to the improvement and expansion of multidisciplinary instruction.

a. Some of these workshops could augment the series sponsored currently by the National Endowment for the Humanities; others could be part of existing National Science Foundation programs; and a new series designed specifically to bridge the gap between the "two cultures" might usefully be sponsored jointly by these two agencies. Such programmatic expansion should be deliberate, long term, and guided by thoughtful evaluation.

b. Additional support for the faculty members participating in these workshops should be expected not only from their institutions but from the various academic discipline societies and associations.

U5: LABORATORY INSTRUCTION IN FOUNDATIONAL CHEMISTRY COURSES

Recommendation:* *Adoption of a standard that all college-level foundational chemistry courses, whatever their student clientele, include substantial and significant laboratory work.

> "When we shall be able to employ in scientific education, not only the trained attention of the student, and his familiarity with symbols, but the keeness of his eye, the quickness of his ear, the delicacy of his touch, and the adroitness of his fingers, we shall not only interest . . . people who are not fond of cold abstractions, but, by opening at once all the gateways of knowledge, we shall ensure the association of the doctrines of science with those elementary sensations which form the background of all our conscious thoughts, and which lend a vividness and relief to ideas, which, when presented as mere abstract terms, are apt to fade entirely from the memory." [James Clerk Maxwell (1831–1879), physicist]

The discussion preceding Recommendation H5 presented an outline of the case for the laboratory component of high school chemistry. Since scientists must "do" things as well as think about them, there has been no lack of recognition of the importance of laboratory work at every stage of *their* education. But, the laboratory is a similarly essential component of foundational instruction in science intended for (and especially if required of) those preparing themselves in disciplines outside the sciences. The case is the same at the collegiate level as in the secondary schools: science is experimental; human beings gather data, interpret it, and organize it; the interaction in the laboratory between nature and the student is an essential ingredient of education.

U5. Whether they are taught to nonscientists, science majors, or chemistry majors, foundational courses in chemistry at the college level must include a substantial component of significant laboratory work.

a. "Substantial" is ordinarily determined locally. But, it is our belief that devotion of less than 30% of scheduled time to the laboratory work in a foundational course is close to if not actually insubstantial. It is of paramount importance that any educational laboratory work be *significant*, not merely trivial or time-spending.

U6, U7: CHEMISTRY FOR NONCHEMISTS

Recommendation:* *Preparation by the ACS Committee on Professional Training of recommendations concerning the content of chemistry courses intended for students who are not majors in chemistry.

Recommendation:* *Development by ACS of curriculum modules in such aspects of chemistry as are germane to the curricula of professional schools in law, business, and the health professions, among others.

We believe that the study of chemistry is good intellectual exercise and that it imparts much knowledge of permanent value and wide applicability; it is, therefore, useful preparation for almost any career. Indeed, it is the centrality of chemistry that makes it a required subject at the introductory level in a large number of science and nonscience curricula. However, chemistry course enrollments in most colleges and universities diminish rapidly as their level rises. Some technical and professional curricula require a second year of chemistry, building on the General Chemistry course that is taken, usually, in the freshman year; but, very few undergraduate students other than chemistry majors are found in the advanced courses which depend on "second year" courses in organic and analytical chemistry and the necessary parallel work in physics and mathematics. Most of the instruction in chemistry departments is for the benefit of students who do not intend to major in chemistry.

Many students who take chemistry because it is prescribed by the curriculum for another major feel "sentenced" to serve out the experience. In some cases the fault lies in the chemistry department: it may have allowed its service activities for other units to get out of tune with their needs; or, it may have gone too far in tailoring such offerings to narrow interests, robbing the study of chemistry of its breadth and vitality. In some cases the fault is wider spread because there is insufficient knowledge on campus of national trends in chemistry requirements of the major professional curricula other than chemistry—in the health professions, for example. In all cases, we believe, the interaction between provider and consumer departments could be improved if guideline information were available from a source committed to the maintenance of quality in chemistry instruction by other disciplines. That source exists: it is the Committee on Professional Training of the American Chemical Society.

U6. The American Chemical Society's Committee on Professional Training, in cooperation with its counterpart bodies in the professional societies serving other disciplines, should make recommendations concerning the level and content of college chemistry courses for students majoring in fields other than chemistry, especially other technical fields.

a. This activity is proposed as an aid to the necessary continuous interaction between chemistry and other departments, not as a substitute for it.

The slow decline in number of undergraduate majors in the liberal arts, of which chemistry is one, has had at least one very undesirable effect: students carrying out advanced work in nonscience fields and in preparation for the professions now frequently lack the necessary background in chemistry and other sciences that, formerly, they would have acquired early in their undergraduate years. In a few areas a whole course in chemistry (or another science) would repair this omission; in most others less time is available and more specific content is required.

U7. The American Chemical Society, through the body described in U3, above, and with the assistance of various of its membership Divisions (e.g. Chemistry and the Law; Chemical Marketing and Economics), should undertake to determine the needs and develop curriculum modules for advanced instruction in such aspects of chemistry as are germane to the curricula of professional schools in law, business, and the health professions, among others. The Society should join with other science societies to develop similar but more general modules in science, its content, and its methods.

U8: LABORATORY EXPERIENCE IN THE CHEMISTRY CURRICULUM

***Recommendation:** Inclusion in the budgets of instrument purchase programs of additional funds to permit development of cooperative mechanisms for the maintenance and repair of such equipment.*

There is widespread concern that both the quantity and quality of laboratory experience in baccalaureate degree programs is decreasing. The requirements for formal laboratory work have always been less in the United States than in other industrialized nations, but increasing costs of modernization, upgrading, or even sustenance of present levels of quality generate pressures which are resulting in even less favorable comparisons than before. Many students awarded bachelor's degrees in chemistry have very limited experience with modern laboratory techniques and even less experience in the design, formulation, conduct, and analysis of experiments. (Students graduating from Cooperative Education programs are a notable exception.) As the content of the chemistry curriculum has become more theoretical, more student time is spent in the classroom and in the pursuit of solutions to formal problems, and less in the laboratory learning and perfecting those techniques which establish and maintain the real contact of a chemist with the material world. Students develop little feeling for the behavior of matter—which, ultimately, is what chemistry is all about.

The advent of the computer has placed additional pressures on laboratory instruction. It sings the siren song of economy through simulation, with additional benefits of tirelessness, cleanhandedness, and freedom from chemical hazard. These attractions (instead of those such as augmentation of the laboratory experience, increase in the scale and sophistication of related data reduction, and the development of broader and more challenging experiments) seem to affect the ways in which the computer is applied in the laboratory. Thus misapplied, the computer becomes another force driving students farther toward the view that chemistry is a game played against skillful opponents (who already know everything that the student is supposed to learn) rather than a way of unraveling and comprehending natural phenomena.

For over twenty years, one of the most effective responses of chemistry educators to the disinclination of students to regard laboratory work as important has been to bring such supervised experimentation closer in methodology and sophistication to the ways that chemistry is practiced in real career situations. At first, experiments in advanced courses were designed to use instrumentation like that used in academic or industrial research; later, as less expensive and more sophisticated versions of these instruments became available, this kind of exercise spread to less advanced courses. The cost escalation of the past ten to fifteen years threatens to wipe out these earlier gains.

The initial cost problem has been attacked successfully by a host of programs. These include industrial donation to education of still useful instruments, and several instrument purchase programs supported generously in past years by the National Science Foundation. Instructional and research instrumentation programs for colleges and universities have helped the improvement of laboratory instruction, as have those which stimulate and support undergraduate and faculty research opportunities. Reinvigoration and expansion of these programs is necessary if the American chemistry graduate of the future is to be capable of the practice and not just the contemplation of chemistry.

One aspect of instrument-basing of laboratory instruction (and research, for that matter) has received much less attention than it deserves, especially if one believes that conservation of resources is an appropriate response to increased competition for resources. That aspect is the repair and maintenance of the complex and sophisticated instruments used in research and instruction. One need not visit a Third World country to see costly instruments out of use because they cannot be repaired. The problem exists even in research universities, where cuts in support staff seem to occur in perfect synchrony with the breakdown of equipment; but it is disablingly serious in smaller colleges and universities which have never been able to budget adequately for in-house maintenance and repair of instructional instruments.

Historically, agencies that grant funds to assist the purchase of instruments and complex equipment for use in education have regarded the maintenance and repair of such items as an institutional responsibility—part of "cost sharing." However the accountants feel about such things, something must be done to assist smaller colleges and universities in keeping their instruments on line. If the demand for direct subsidy of maintenance costs is to be restrained, other ways of addressing the problem must be devised.

The attention of the Task Force has been drawn to several approaches to meeting this need. Some colleges and universities close to each other have been able to share instrumentation and thus reduce the scope required of both initial purchases and later maintenance. In a few cases, industrial research laboratories nearby have made their instrument repair staffs available, such cooperation being a component of a broader academic-industrial collaboration. There are several instances of other kinds of inter-institutional cooperation. An especially attractive one (because of its continuing success) is that centered on Georgia Institute of Technology, which cost-shares with 60 smaller institutions a service designed to take institute instrument repair specialists to where the trouble is.

U8. The National Science Foundation and other agencies supporting the purchase by colleges of instructional research instruments should include in the budgets of these programs additional funds to permit experimentation, demonstration, and implementation of cooperative mechanisms for providing maintenance and repair service for such equipment.

a. Since much government support of instrument purchases is tied to their use in faculty and undergraduate research, we urge that realistic note be taken of the differences in the professional situations of the faculty member in a small college and one in an institution geared to graduate education and research in making awards for the support of the general costs of research. More than one person has pointed out to us that the small college faculty member who carries on a program of research with undergraduates "produces good graduate students in chemistry, not necessarily publications."

U9: THE APPROVED CURRICULUM IN CHEMISTRY

***Recommendation:** Sponsorship by the ACS of the preparation of position papers providing advice and guidance to faculty members on ways to include or improve instruction in the undergraduate curriculum on a number of specific topics and areas.*

Some of the strength of undergraduate education in chemistry in the United States arises in the multiplicity of opportunities available: a student can choose a college and a program that fits his or her interests and needs. At graduation, however, the interests and needs of potential employers enter the picture. Difficulties occur when the preparation of a student differs substantially from that which is appropriate and expected. The reduction of such difficulties is what has impelled the design of curricula whose content and, one hopes, intent are agreeable to the parties on either side of the meeting point.

The Committee on Professional Training of the American Chemical Society was established to determine and to promulgate "minimum standards" for the education of a baccalaureate chemist to practice chemistry as a professional. Over time, the "minimum standards" have given way to "guidelines," in recognition of the pluralism of both the academic community and the world of professional activity, but the Committee's program continues to provide assurance that graduates of an approved curriculum are qualified to function as chemists at a baccalaureate level of professional preparation. The Committee undertakes to understand what a chemist is supposed to be able to do and to enunciate the characteristics of the undergraduate education that will prepare one to be a chemist.

There has always been strong opposition to almost any position taken by the Committee, especially from schools that did not conform to the mold (it is a rather elastic one) deemed proper by the Committee. Fortunately, the Committee has limited its efforts to the publication of a list of "approved" programs that meet its guidelines. It has never forced an approved program on all the students in a given college; but it has insisted that all schools with approved programs be prepared to offer and, in fact, do offer a curriculum of that character and scope. And, application for approved status is completely voluntary on the part of an institution with a program to be considered.

We deal in other sections with some broad aspects of the structure and work of the Committee on Professional Training. Here, our concern is finer detail—the content of the approved curriculum—and it responds to opinions expressed by educators, employers, *and* students. Some feel the curriculum described by the Committee's guidelines is so rigid as to inhibit desirable experimentation and innovation; others would prefer greater specificity, especially if the curriculum included thereby some area felt to be neglected. Some feel that the curriculum is already overcrowded and needs purging; others believe that the cavities in the curriculum are more harmful than its bulges.

The following brief paragraphs will serve to identify some of the concerns expressed to the Task Force and shared by some of its members.

Courses concentrate increasingly on chemical principles that underlie current chemistry research and, to a lesser extent, practice. The result has been a weakening of *historical perspectives and humanistic values* in terms of which all chemistry majors should be prepared to understand the place of chemistry in our culture.

The full-year *organic chemistry and physical chemistry* courses are utilized (particularly in the large universities, which set the content and tone for nearly everyone else) by more students majoring in fields that build on chemistry than by those majoring in chemistry itself. Yet, as these courses have evolved they have tended to concentrate increasingly on topics that have microscopic orientation (fine for future graduate students in chemistry) to the exclusion of those that have a macroscopic orientation (needed by all others who are enrolled).

Much student interest in chemistry stems from contemporary applications to the life sciences. There is not space in the chemistry major's curriculum for much formal instruction in *biochemistry* and *molecular biology*, so room must be made for them in *organic chemistry*.

Most chemists are employed by industry, and most such deal every day with some aspect of *polymer and macromolecular chemistry*, topics which are coherent and mature. Both are almost ignored in the curriculum in spite of their critical relevance to career opportunities and the ease of their incorporation into courses in analytical, inorganic, organic, and physical chemistry.

There is a widening gap between academic coverage and career practice in the applications of *computers and computation* to the management of information, control of experiments, and development of models in both chemical research and nonresearch activities. Since computer-assisted instruction and experimentation are commonplace in colleges and universities, the problem is one of balance, not one of exposure.

Students see limited applications of *probability and statistics* in topics ranging from the kinetic theory of gases to the x-ray determination of protein structure. Yet, examination of chemistry curricula shows virtually no formal coursework on mathematical probability or, even more important to a practicing chemist, on the statistical design of experiments, reduction of data, or the deduction of conclusions.

Chemistry faculty must share the burden of a criticism heaped on the whole of education: that its graduates are deficient in *communication* skills—inept at expressing their ideas or reporting the results of their work either orally or in writing.

Chemical economics is not part of the approved curriculum, yet economic factors will determine the course of the professional lives of most chemists. Good text material that could be incorporated in a variety of courses that *are* in the curriculum is readily available.

Most chemical educators and graduate chemists are aware of safe methods for the conduct of experiments and have some knowledge of how to handle emergencies. Unfortunately, practice lags far behind awareness and formal instruction is virtually nonexistent. Education with respect to *safety and chemical hazards* should start with the early development of sensitivity to the problems, illustrations of good practice, and insistence upon it.

Formal training in *chemical information retrieval* is seldom included in the chemistry curriculum, yet every professional chemist must use a variety of complex printed sources as well as an increasing number of computerized databases. Further, the pace of change in information systems is greater than can be accommodated by self-help efforts.

Since chemistry is a growing, changing, evolving science, it should surprise no one that curriculum issues such as those just described continue to arise. The time available for baccalaureate professional education is relatively inextensible, however, and curriculum change must procede by evolution, substitution, and re-synthesis rather than by addition and accretion. We suspect that the Committee on Professional Training has considered relatively recently all of the curriculum problems mentioned above and more, yet the impression held by many is that nothing is being done.

The Task Force believes that it is possible to discover ways of bringing into the existing curriculum appropriate content from problem areas like those listed above. The problem is more one of pedagogy, the work of faculties, than it is of standard-setting, the work of the Committee on Professional Training. A useful model is the resource volume on physical chemistry topics important to chemical engineering students presently in preparation under ACS sponsorship. This volume derives from much person-to-person discussion, several symposia, and a working conference of physical chemists and chemical engineers (from both the industrial and academic communities) interested in solving the problem.

U9. The Society Committee on Education of the American Chemical Society and the ACS Division of Chemical Education should sponsor symposia and carefully defined and designed studies to examine a number of specific problems with the approved (professional) curriculum, and with those of its components that are utilized regularly by students majoring in other science fields. Among such problem areas are the following: historical perspectives and humanistic values; the organic chemistry and physical chemistry courses; biochemistry, molecular biology, and organic chemistry; polymer and macromolecular chemistry; computers and computation; probability and statistics; communications; chemical economics; safety and chemical hazards; and chemical information retrieval. These studies should generate resource materials and position papers to provide advice and guidance to college and university faculty members on optimal ways to improve or include appropriate instruction in these areas in the curricula pursued by chemistry majors and by students in other fields of science.

U10: CHARACTERIZATION OF CAREER OPPORTUNITIES IN CHEMISTRY

Recommendation:* *ACS consideration of how best to characterize opportunities in chemistry and the expectations of employers, identify necessary curriculum and resource elements, and utilize results of research to improve chemistry education.

At the present time, over 85 percent of all baccalaureate degrees in chemistry are awarded by colleges and universities on the Approved List of the ACS Committee on Professional Training. Of all baccalaureate chemists, about 40 percent move immediately into fields with other names, though they may be very close to chemistry (e.g.

medicine, agricultural chemistry, chemical engineering). The 60 percent of bachelor's degree recipients who retain the label *chemist* split about equally into those who go on to advanced work in chemistry or closely allied fields, and those who enter (or return to) industrial employment immediately. Since it has been half a century since a majority of doctorates in chemistry sought careers in education, it is no error to conclude that at least 96 percent of each year's group of graduating chemists will seek and find professional employment that is not academic but industrial or like industrial.

Organizations and corporations that employ many persons educated as chemists ordinarily support broad scientific programs. They can accumulate specialists of various sorts to achieve any flexibility and diversity that may be required in the lower levels of their organizations, but most promote quite significantly on the basis of the way in which an individual acquires that flexibility and diversity of professional competence within himself.

Employers of small numbers of graduate chemists tend to have more specific needs, and the match of organizational and personal specifics is often important. But small organizations have low institutional inertia—their needs can change dramatically in short times. Individuals must be able to adapt to such changes.

The wide spectra of career aims (for individuals) and opportunities (from employers) force impossible objectives upon the prescription of any curriculum other than those that provide maximum possible flexibility consistent with wise guidance of student learning. Although the Committee on Professional Training has attempted to follow this concept, the compromises it has been forced to make have led to what most of its critics and some of its friends describe as a degree of specificity that may be contrary to the interests of many students and in poor tune with the longer-range needs of those who will be their employers.

Some colleges and universities permit and even encourage chemistry students to graduate without satisfying the full requirements of the curriculum spelled out by the Committee; others simply ignore the rubrics of the curriculum (still specified in terms of "courses" and the "traditional areas" of chemistry) and operate their own educational patterns within the scope of "equivalent experience." Yet, whether its guidelines are obeyed or not, the Committee has a powerful and earned presence and reputation and its careful pronouncements are heard and learned, if not followed consistently.

Issues like those implied by the comments appended to the text of the preceding recommendation are undoubtedly discussed by the Committee and acted upon by them. Yet, there is little information available about those process aspects and the same concerns are expressed repeatedly over time.

Expression of these concerns may represent partial answers being offered to the question "What is a chemist?"—a question that the Committee on Professional Training has continuously before it. The vitality of the chemical sciences guarantees that that question can never be given a single definite answer—even though the Committee discharges one of its major responsibilities by describing a single curriculum.

The Task Force believes that it is appropriate at this time, when the practice of chemistry is changing rapidly and increasingly diverse pressures operate on colleges, for a substantial effort to be undertaken to determine the kind of preparation which might fit students best for careers in chemistry as well as careers in related areas. This effort might profitably be approached from the perspective of the career itself, rather than from that of the educator who may have a limited view of careers related to chemistry as they actually exist. One is faced immediately with the fact that there is a broad spectrum of careers in- and based on- chemistry, and that they might require equally diverse preparation on the part of the future professional. It is for this reason that we feel the first step should be to determine how to characterize careers related to chemistry and to identify, insofar as possible, the kinds of professional education needed to prepare for them.

We would like to have the Committee on Professional Training undertake this effort itself, but recognize that it is a considerable task that the Committee might not be able to manage along with its other commitments. Therefore, we propose an ad hoc body to undertake this study—one that will take advantage of the experience of the Committee, but which has a broader base in both the academic and industrial communities.

U10. The Task Force recommends that the President and Chairman of the Board of the American Chemical Society either select an existing committee of the Society (perhaps the Society Committee on Education with some augmentation of membership) or appoint one ad hoc to consider how best to: (a) characterize opportunities in chemistry and the expectations of employers; (b) identify necessary curricular and resource elements; and (c) utilize the results of research on teaching, learning, and instructional technology to improve the effectiveness of chemistry education. This committee, whether selected or appointed, should include: (1) current members of the Committee on Professional Training (CPT): (2) former members of CPT; (3) representatives of a range of types

of industrial employers of chemists; and (4) members of the Society who have not been associated with CPT.

By *opportunities in chemistry,* we mean those accessible to chemists at the four traditional levels of graduation—associate, bachelor, master, and doctor; by *necessary elements,* we mean those that, if not available, will constrain the career options of individuals completing each of the levels of education mentioned; by *improvement in effectiveness,* we mean such sequelae as will preserve and enhance the flexibility of curricula, broaden the opportunities available to graduates without sacrificing the quality of their educational achievement, improve the match between courses of study and the long range requirements of employment, and make the educational experience more efficient and satisfying.

a. Since the results of such a study are intended to complement the continuing deliberations of the Committee on Professional Training, the report should be directed to CPT after review by the Society Committee on Education.

U11: MISSION AND STRUCTURE OF THE ACS COMMITTEE ON PROFESSIONAL TRAINING

Recommendation: Consideration of the mission of the ACS Committee on Professional Training.

Several sources of potential new responsibilities for the ACS Committee on Professional Training can be identified at any given time. For example, in addition to this Report (which proposes a number of new tasks for the committee, some continuing, some ad hoc) individuals and institutions propose regularly that CPT undertake the same kind of supervision of doctoral education in chemistry that it has exercised on behalf of that at the baccalaureate level.

At the present time, the time and effort of the Committee on Professional Training appear to be devoted fully to maintenance of the Approved List of baccalaureate chemistry programs in college and universities. The changes that have occurred in the past decade in the professional practice of chemistry and sciences related to chemistry have expanded enormously this supervisory task of the Committee on Professional Training. Additional obligations, especially if they are continuing, may be beyond the capacity of the Committee to accept or discharge.

There are risks in asking CPT to do more than it now does. The Committee has an excellent reputation for objectivity and firm fairness. Over a long period it has discharged a sensitive and difficult task with unchallenged concern for quality, high integrity, and demonstrable openness. Conceivably, the imposition of additional obligations on the Committee could weaken the thrust of its present efforts—a result wished-for by no one.

The Committee itself can certainly determine whether or not its present duties permit its acceptance of one or more *ad hoc,* time-limited tasks (such as several proposed in this Report). But another body should provide advice on the assignment to it of additional permanent obligations.

U11. This Task Force recommends that the President and Chairman of the Board of the American Chemical Society assign to an existing committee of the Society, or to the ad hoc committee described in U10 above as its second major task, the responsibility to consider the intended, actual, and appropriate future mission of the Committee on Professional Training and to recommend such specific changes in mission, structure, or both, as may be required to maintain and extend the effectiveness of the Committee, whether continuing as at present or in some new form(s).

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a. The report of the proposed committee should be reviewed by the Society Committee on Education and by the Committee on Professional Training. But, since its content may foreshadow changes in the assignment of CPT, the Board of Directors and the Council should be the ultimate recipients of the report.

U12: INFORMATION MANAGEMENT

Recommendation: ACS leadership of efforts to modernize the concept and structure of technical libraries.

Very early in its history, the American Chemical Society recognized a responsibility twin to that of reporting discovery and observation in chemistry—the responsibility to assist the management of the body of information thus created and expanded. The Society's *Chemical Abstracts Service* is the contemporary manifestation of that recognized and accepted responsibility.

Every chemist is both a creator and manager of information. Much of the formal education of a chemist is given over to activities designed to teach the state of the science and the basic techniques for adding to its store of knowledge. Some time (but less than formerly) is devoted to instruction and practice in the now burgeoning area of information management. Students do gain, almost osmotically, some ability to use the traditional repositories of fact and opinion—journals, books, abstracts, indices, patents, and the collections of them called libraries. But the advent of the computer has increased both the varieties of ways in which traditional collections can be probed and the rate at which new and possibly substitute kinds of collections are created, developed, and emplaced.

The ease in the speed with which computer techniques can be applied, and the continued rapid fall in computing costs, have resulted in the spread of new techniques that do not employ the human mind as intermediary, but apply selected data directly to the design, conduct, analysis, interpretation, and reporting of experiments. The trend is clear and will continue. But, since the costs, though falling, are still substantial, teaching of these techniques and practice with them is done less in colleges and universities than in the industrial laboratory.

The nature of the technical library is changing. No longer only a collection point, it is the center of manifold information gathering and management activities. Every discipline is contributing to this change; every discipline must be able to profit from it.

U12. The American Chemical Society should identify an existing committee or create a new one to provide leadership within the whole scientific community for analyzing the needs and opportunities and for proposing implementation nationwide of programs to modernize the concept and structure of technical libraries. This committee should draw on the expertise of Chemical Abstracts Service, but should include other individuals skilled in information science and the use of computers for information management in both the industrial and academic communities. Among the committee's concerns should be the use of these techniques for formal and informal education, and the training of individuals for careers in chemistry applications of information sciences.

Recommendations on CAREERS IN CHEMISTRY

C1 Economic Restraints on Career Development
C2 Arbitrary Restraints on Career Development
C3 Continous Learning

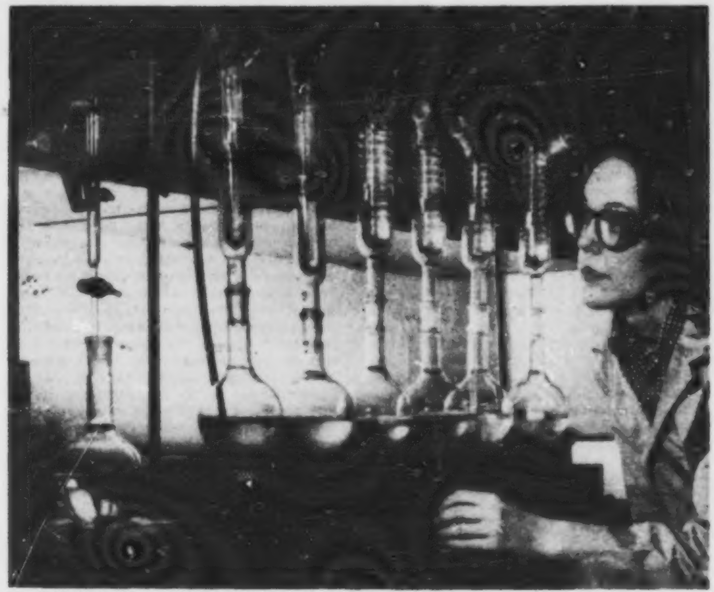

Photo: USS Chemicals—Division of United States Steel Corporation

The chemical sciences and chemistry education cannot achieve their maximum potential unless those who have the interest and intellectual capacity enjoy equal access to entry and advancement in chemistry and related disciplines.

C1: ECONOMIC RESTRAINTS ON CAREER DEVELOPMENT

Recommendation: ***Government and industrial support of a program of postdoctoral appointments for research on problems of national concern to assist bridging temporary differences in employment demand and scientist supply.***

One of the hazards associated with defined pathways for professional preparation arises in the implicit assumption that the supply of graduates and the entry-level demand for their services will correspond. In comparison with the situation in the performing, graphic, and plastic arts, where there is virtually no market influence on the production of graduates and only a vaguely defined market for their services, that of the chemical sciences is comfortable indeed. It is believed that in the chemical sciences there is a reasonable balance between the supply and demand for new professionals, whose numbers are relatively stable, and that incentives provided by salary and other differentials will act quickly to smooth any imbalance.

Unfortunately, the rate of change in industrial employment needs is typically an order of magnitude faster than that of academic preparation of scientists at any particular level of education. For example, the ratio 1981/1983 of offers of entry-level positions was approximately 2 for Ph.D. chemists and 8 for B.S. chemical engineers, while the ratio of degrees awarded was essentially 1; and demand (new hires) tends to drop 3–5 times as rapidly as it rises. Further, economic driving of industrial demand causes fluctuations in both its scale *and* its composition; for the latter there are no quick-acting analogues in the educational stream.

An especially pernicious corollary to the mismatch between rates mentioned above is the paucity of recognized, experience-building interim positions for well qualified graduates who, through no fault of their own, enter the marketplace at a time of glut. When conditions improve the following year or perhaps the next, employers look at the current year's crop to the virtual exclusion of those passed-by in the preceding year or two. There is a premium on freshness for scientists as well as fish.

It is an appropriate national concern that there be developed a mechanism to dampen wide oscillations in the number of employment opportunities available to the number of scientists being educated today—a number which is in good balance with *long-term* average demand. The academic postdoctoral research position has served to provide further (sometimes additionally diverse) education to persons intent on academic careers; and the aggregate of such positions (which has grown steadily for several decades) provides useful interim employment for other new scientists when industrial demand is slack. But, if there is a mismatch between what universities produce and industry needs, postdoctoral positions in universities, by their very nature, do little to address it in a useful way. A national postdoctoral system that could provide the dampening needed should be centered outside academe. It is highly desirable that the number of such positions located in industrial, institutional, and government laboratories be increased. Although there are some temporary or revolving postdoctoral research appointments in industry, that sector, faced with the occasional necessity to cut back on the employment of scientists, has found it difficult to make a continuing investment in temporary, inexperienced scientists, though such an investment could permit an industrial laboratory to undertake research or development studies without long-term commitment to either programs or personnel—a kind of flexibility that industry seems to want (and academe ought to).

The various research and testing laboratories of Federal, state, and local governmental agencies employ large numbers of scientists on regular and permanent professional tracks. The Federal entities, at least, provide also a number of temporary or revolving postdoctoral research associateships (the recruiting competition for the program is administered by the National Academy of Sciences—National Research Council); the program, however, is small in comparison to need and, in spite of substantial effort on the part of some Federal agencies, almost unknown. The Task Force believes that this and similar programs should be better publicized and that they should be expanded, not in mission directions, but toward the solution of problems in applied science germane to matters of serious national interest—such problems have long-term industrial as well as governmental and disciplinary dimensions, and could maintain the "freshness" (for purposes of eventual industrial employment) of the young scientists who worked on them for, say, one or two years.

C1. This Task Force recommends that the United States Government establish a new program of postdoctoral research on problems of national concern which could support as many as 200 chemical sciences appointments per year in Federal, industrial, or institutional laboratories. Such appoint-

ments would be tenable for a maximum of two years, and their number an addition to those presently funded through grants for fundamental research. The American Chemical Society should assume leadership of an effort to secure parallel expansion of such appointments under industrial sponsorship and, in other ways, assist dampening of wide swings in the annual numbers of employment opportunities.

C2: ARBITRARY RESTRAINTS ON CAREER DEVELOPMENT

Recommendation: ACS sponsorship of efforts to identify and correct arbitrary restraints on women preparing for or practicing the profession of chemistry.

The chemical sciences and chemistry education cannot achieve their maximum potential unless those who have the interest and intellectual capacity enjoy equal access to entry and advancement in chemistry and related disciplines. This objective should be a basic principle of the chemical profession and should be both addressed and exemplified by the American Chemical Society.

Statistically, the members of some groups in the nation's population, though qualified individually, continue to be underrepresented in the chemical professions, particularly at the upper levels of career development; women and minorities still constitute only a small percentage of the total number of chemical scientists, especially in major universities and small corporations. This situation arose from historical patterns which, in turn, originated in arbitrary restraints on entry into the profession and on later advancement. Extensive efforts have been made to modify the old patterns, reverse their effects, and thus remedy the situation—but it persists.

Women are identified legally as a minority segment of our population. That they are, in fact, both an actual majority of the population and the largest of the legally identified minorities merely intensifies the reaction to the injustices experienced by women who pursue careers in fields long dominated by men.

Some of our informants, women among them, hold that serious discrimination against women no longer characterizes the chemical sciences. They argue that the present underrepresentation simply reflects the length of time it takes to change the perceptions and understanding of young women at the moments when career-related decisions are made; and they assert that there continue to be improvements in the career situations of women in chemistry.

Problems of women in chemistry are similar in many ways to those of other minorities; but, because they constitute the largest minority, a thorough study of their difficulties within the profession could have important teaching quality with respect to the problems of all minorities.

C2. The American Chemical Society, through its Women Chemists Committee and other appropriate bodies, should sponsor a conference to identify the difficulties encountered by women qua women in preparing for or practicing the profession of chemistry. Following that conference, a specific charge should be made to an appropriate Society body to seek actively solutions to these problems and removal of such arbitrary restraints on career development as may have been identified by the conference. If this approach proves successful, the Society should apply it to the difficulties in the same areas experienced by minority, handicapped, and other special segments of the profession and the profession-to-be.

a. The Task Force urges that the conference consider questions like the following:

Are there factors that operate currently to impede the recruitment and advancement of women in chemistry, or have such factors as existed in the past been eliminated?

Are there constraints associated with certain career paths that effectively inhibit women chemists from pursuing these paths?

Do such factors or constraints tend to steer women into careers that are less challenging or rewarding than those open to men?

Are there factors, real or perceived, that operate to discourage young women from choosing careers in the chemical sciences?

What should be done to change the patterns that discourage women students in grades 6 through 10 from making career decisions that reflect their earlier enthusiasms for science? In particular, what should be done to make chemistry an attractive career for women?

b. Since the problems that do exist are more because of the attitudes of men than of women, men as well as women should be involved in planning the conference, conducting it, and implementing its recommendations.

C3: CONTINUOUS LEARNING

Recommendation: Increased development, testing, and evaluation of electro-optical systems for continuing education; expansion of ACS continuing education services.

The tradition of continuing personal and professional education is a very old one in the United States. It has been sustained by the involvement not only of educational institutions but of professional societies, licensing boards, employer entities and groups, and individual providers. The purposes of such continuing education are almost as numerous as the individuals so engaged; but, the major categories, apart from cultural and educational enrichment in service of personal objectives, appear to be:

Maintenance: work intended to maintain and update the previous formal education of the individual; typically, such work is organized into "courses" similar to those taught in colleges and universities, and brings to the graduate professional the content and level of such instruction.

Completion: usually courses, but in areas which complement or supplement the work (in both major and minor fields of study) taken by the individual when a student: in the case of a chemist—a follow-up course in, say, physical chemistry; an additional, higher level course in mathematics or physics; work in economics, marketing, or business law missed during initial professional education.

Proficiency acquisition: the largest category and the most varied in mode and scale of individual activity: work designed to yield (through limited, often intense study) new or enhanced proficiencies in the use of new experimental techniques; report writing and technical communications; recent advances in methods, theory and practice; etc.

Continuing education is accomplished through a variety of formats: "open university"; correspondence; typical school, college, and university classes; less formal (and other) modes which involve just the individual student at the time of instruction; and tutorial and small group instruction. Twenty-five years ago, continuing education, like initial education, was delivered primarily though the printed or directly spoken word. More recently a host of electro-optical techniques have gained prominence (prerecorded audio and video materials, electronic blackboard and teleconferencing, and a number of different kinds of interactive, computer-based methods)—but with a trend favoring class or institutional settings.

The rapidly spreading use of electro-optical techniques, unlike the "blip" of "teaching machines" some years ago, exhibits such momentum that one must conclude that a revolution in educational technique is underway that will be as sweeping as that occurring in the workplace. In some colleges and universities there is concern that students no longer know how to learn from books, so acclimated have they become to nonprint presentations. Unless there is parallel development of new techniques affordable by individuals, continuing education in the future will be as place-bound as initial education has been and will continue to be. This would reduce the scale of such activity sharply, since much of continuing education is now accomplished on an individual basis and at home.

C3. Federal agencies, private foundations, and scientific societies concerned with support of education in science should devote substantial resources to the experimental development, testing, and evaluation of electro-optical technological systems for providing maintenance, completion, and proficiency acquisition types of continuing education, with special emphasis on the accessibility of high quality instruction to individuals away from the workplace. Specifically, the American Chemical Society, through its Education Division, should continue to develop and expand its self-supporting audio, video, computer-based, and other electro-optical continuing education services to both individuals and groups.

Recommendations on INDUSTRY AND EDUCATION

I1 Academic-Industrial Cooperation

I2 Coordination at the Industrial-Academic Interface

Photo: W. R. Grace and Company

The chemical industry can bring substantial human, intellectual, and financial resources to bear in aid of the structure and processes of education.

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I1: ACADEMIC-INDUSTRIAL COOPERATION

Recommendation: Strengthening and expansion of activities that bring the resources of the chemical industry to bear on improvement and support of science education at all levels.

Historically, a variety of interactions between industrial and educational institutions made major contributions to the growth and eminence of the nation in pure and applied science; chemistry was the earliest of the sciences to enjoy this florescence. Some of these interactions have persisted during the last twenty-odd years (continuing education programs, consulting by faculty members, industrial support of some academic research, etc.), but many have shrunk or disappeared altogether as Federal funding of basic research, development in special areas, and support of many programs to improve science and technical education have put money into academic institutions on a grand scale.

Since the last century, academic scientists and industrial managers have dealt with each other as producer and employer, respectively, of the highly educated individuals needed by the private technical sector. This relationship has grown steadily in size and occasionally in tension. Private industry will never match, much less supplant, the scale or variety of Federal involvement in science education and academic research, but the recent redevelopment of common interests into shared and collaborative activities cannot but benefit all three—education, industry, and government.

Industry and business have the capability of contributing by participation in many of the formal structures and processes of science education, and the desirability of their doing so is becoming more generally accepted. Present educational modes can be supplemented with resources available from scientists and institutions outside the education establishment. Scientists employed by industry can provide professional skills as adjunct or exchange teachers at all levels of education, and can contribute in many ways to the development of a populace that is scientifically aware and literate.

The need for science literacy of the general public is beyond debate. Further, most of our local and national leadership are nonscientists, and their education for leadership must include adequate grounding in the content and methodology of science. Industry is a direct victim of a scientifically illiterate population.

In response to these needs, the chemical industry can bring substantial human, intellectual, and financial resources to bear in aid of the structure and processes of education. To the extent that industry recognizes that the future strength of our technological society depends on the present student body, industry will recognize that it is in its interest to divert a significant portion of *present* resources to the education of future generations of citizens and scientists.

In the course of this study, the Task Force has observed many instances of viable interactions between educational institutions and nearby industries. Some industrial corporations are sufficiently large that their participation in such activities extends well beyond the local scene to the state and region, and some operate at the national level. Where chemistry is concerned, the nationwide system of local sections (membership) of the American Chemical Society provides both a forum for planning and action and a natural mechanism for coordination that is *local* in the best sense of the word. In the paragraphs below are examples of local activities that could serve as models for widespread application.

Elementary Schools. Industries have recognized the need for sound education in the schools in many ways: creation of award programs for master teachers; opening plants and laboratories to guided teacher tours; establishment of special funds to purchase science demonstration and other unusual teaching equipment and supplies; support or award of scholarships to teachers taking science updating work at workshops, institutes, and in summer sessions at colleges and universities; providing their science personnel for special meetings, lectures, workshops, demonstrations, in-service courses, and other activities aimed at strengthening science education; participation in varied efforts to acquaint the public with the roles of science and technical endeavor in contemporary society; work to increase those aspects of public awareness that can result in improved local support for local schools; and sponsorship of teacher institutes and workshops on science teaching.

High Schools. Industry interactions with high schools embody all of the elements just listed and others in addition: donation of technical library materials; encouragement of industrial scientists to undertake part-time teaching or teacher assistance positions in high school science programs; establishment of special funds to acquire the laboratory equipment and supplies necessary to assure that students have high quality, up-to-date experiences in basic science; sponsorship of student science fairs and projects and related awards for excellent achievement; student tours of industrial plants and laboratories to emphasize the variety of technical employment and assist guidance counseling in the schools; provision of summer appointments in research, marketing, technical services, personnel services, and other areas, for qualified science teachers (reported more frequently for chemistry than for any other science or technical area!); support for "career days" and other counseling activities to provide sound information to students on career choices and employment opportunities; provision of internships to science-interested students after high school graduation but before college to give them a taste of technical employment in industry, as well as remunerative summer employment; and support of ACS local section efforts to improve high school chemistry teaching.

Post-secondary. Community colleges, four-year colleges, and universities enjoy a still wider spectrum of interactions with industry, including all of the kinds mentioned above and the following in addition: donation, sharing, and exchange of research instrumentation; utilization of faculty research skills, as consultants and as summer and sabbatical employees; support for undergraduate summer research; participation in formal Cooperative Education programs for chemistry undergraduates; provision of pre-research summer appointments for chemistry graduate students; support of academic fellowships, graduate and undergraduate research assistantships, and teaching assistantships; development and support of continuing education programs for industry employees; establishment of discretionary funds in chemistry departments to support educational activities or purchases for which institutional funds are not or cannot be made available; exchanges of qualified scientists between industry and academe (adding to the experience and perspective of both); support of student travel to regional scientific meetings and to industrial plants, research, and development laboratories; funding of faculty research projects; support for faculty work on research of specific interest to an industrial sponsor; sharing of library resources; interconnection of computer systems; consultation on curriculum content and development for appropriate, accurate, and timely reflection of industrial research interests and needs; provision of instructional materials dealing with industrial research interests and needs; provision of instructional materials dealing with industrial processes and major product groups; and rostering the skills of retired industrial scientists.

This listing is by no means exhaustive, but it shows the breadth of activities which have developed in various places as local industries and educational institutions discover and act on their common and mutual interests.

I1. The Task Force recommends strengthening and expansion of the wide spectrum of activities that bring the resources of the chemical industry more effectively to bear on the improvement, support, and service of education at all levels. This expansion is important in technical areas, but it is critical in the wider domain of the public understanding of science. The local sections of the American Chemical Society are natural sources of knowledge, interest, talent, and energy for such efforts.

I2: COORDINATION AT THE INDUSTRIAL-ACADEMIC INTERFACE

Recommendation: Establishment of an ACS staff Office to deal with activities at the academic-industrial interface.

The text of the preceding recommendation (I1) contains lists of some of the ways in which the resources and expertise of industry are being brought to the service of education at various levels, and of some of the less conventional ways in which schools, colleges, and universities, and their faculties, are meeting the needs of industry and business.

No one is concerned about *continuing* exploration of industrial-academic interactions; for, after all, both sides of the interface are changing continually and their ways of relating to each other must also. Many are concerned, however, about the continued nature of much of this exploration—about its never-ending, repetitive, wheel-reinventing quality; the lists of recommendations from successive conferences on the subject often have 75 percent redundancy, even after application of a correction for cliches. For example, it is highly likely that sometime later this year (and probably next year as well) there will be a major conference exploring problems at the interface between the industrial and academic worlds. (The writer of this paragraph has attended four such conferences in the past eight years and been a speaker at two of them.)

One hopes for increase on a national scale of the number and scope of interactions like those described in the text of the last recommendation. Virtually all of those activities started at the local level, because there was communication between interested persons on both sides of the interface and ways were found to turn those interests into action. Earlier it was noted that local sections of the American Chemical Society can and do play important roles at this interface. An example of a new kind of effort is that of the Central North Carolina Section, whose Academic-Industrial Matrix (AIM) was created to coordinate and facilitate a wide spectrum of activities bringing academic and industrial chemists together to work on solutions of problems of mutual interest.

The governance structure of the American Chemical Society contains numerous bodies with interest in the interface: Corporation Associates; the Society Committee on Education; the Committees on Local Section Activities, Professional Relations, Project SEED, Professional Training, the Handicapped, and others—all working under the general oversight of the Board of Directors or Council. But, in spite of this extensive interest, concern and proctorship, the level of action is lower than we feel it must be.

I2. The American Chemical Society should establish a staff Office to deal with the numerous and diverse activities at the academic-industrial interface, so that the resources and potential of both communities may be brought more effectively to bear on the improvement of both science education and the public understanding of science through education.

a. This staff function could be created simply by expanding that presently concerned with Cooperative Education, one of the most effective kinds of interaction between industrial and collegiate institutions. As the principal coordinating body for the Society's activities related to education, the Society Committee on Education should assume leadership in developing a proposal to the Board of Directors concerning the responsibilities, role, support and funding of such an Office.

b. An early task for this Office should be review of the recommendations of recent Society conferences and workshops on problems at the academic-industrial interface to determine which are being implemented and which are not. Successful implementation on the local level of suggested programmatic activities should be publicized and other local foci of interest stimulated and supported in their efforts to emplace such activities. Recommendations for new policies or modified statements of policy should be tracked and efforts made to assist the clearing of the docket.

c. The Office should devise strategies for using existing Society communications networks to disseminate information about successful efforts to solve problems at the interface and about new kinds of local and area attention to education that seem to be helpful, and in other ways should assist and reinforce local efforts.

MONEY

The various initiatives recommended by this Task Force would require both public sector and private sector financial support, directly and indirectly. In this section we indicate levels of expenditure that seem appropriate for the objectives of the highest priority recommendations.

The recommendations to the United States Government of highest priority have to do with improvements in the qualifications of teachers (A1) and in the quality of instruction (E5). The Task Force believes that a broad spectrum of in-service workshops, short courses, and institutes for teachers (A1) offers the best hope for improving and maintaining the qualifications of those who teach, at every level. While the NSB Commission on Precollege Education recommended a five-year effort of this kind, we believe that a smaller but permanent program is necessary. Over a period of 4 to 6 years, it should be possible to phase-in a program which would be staffed adequately and reach a reasonable fraction of high school and pre-high school teachers each year. The costs would depend on the mix of program durations and locations. We recommend that the direct and institutional indirect costs of instruction, as well as certain of the participant costs be provided by the Federal Government at a steady state annual level of $200-250 million. State sharing of the total costs of such programs would be expected through their support of released time, continuation and outreach efforts, facilities improvement, long term salary augmentation, additional funds for operations, etc.

A major factor in improvement of the quality of instruction could be the Federally-supported Regional Science Centers, an eventual 10 being proposed by the Task Force (E5). The focus of these Centers would be on materials and new methodologies, though activities in those areas cannot be divorced from concern for subject matter. An annual Federal expenditure of $10 million for these Regional Centers is recommended. A separate research and development center oriented specifically toward new instructional *technologies* should be created also; the recommended level of Federal support is $2 to $5 million per year. As these techniques become more widely dispersed in the schools, this particular center might acquire a more diversified mission and be regarded at least in part, as an eleventh regional center. [Both these aspects of the Center program were recommended by the NSB Commission.]

The highest priority recommendations by the Task Force that involve direct expenses to States are the raising of teacher certification standards in science and mathematics (E1, E4, and H2), related improvements in teacher compensation and conditions of employment (E4 and H2), and increases in the amount and level of science and mathematics taught to all students (E1, E2, H3, and H5). Full implementation of these recommendations would entail substantial costs to State education agencies and local school districts. Some of these would be direct costs: better facilities, additional laboratory instruction, higher pay for teachers in demand in alternative markets, increased costs for operations, etc. Some would be indirect costs: high expectations and standards (for people on both sides of the desk), increased certification requirements, improved conditions of employment, organizational changes, etc. Each state, municipality, district, and school has its own unique mix of problems and opportunities. It is not possible to make estimates of additional costs that are satisfying in their detail.

It is possible, however, to indicate an appropriate level of increased expenditure by focussing on annual expenditures per pupil. We estimate that the improvements in science instruction contemplated by our recommendations for the elementary schools could be bought for an annual additional expenditure of $100 per pupil, including a portion of teacher salary improvement. At the high school level the additional costs might be slightly less, higher intrinsic costs being offset in part because there is already some good science instruction to serve as a base in almost every part of the country.

These estimates of additional costs may be low, but not by a factor as large as 2.

Many of the Task Force recommendations to scientific societies relate to the highest priority in that set—formation of a National Council to lead in many ways the improvement of both precollege education in mathematics and science and the public understanding of science. The major scientific and technical societies could mount a likely highly effective effort through contributions aggregating $1 to $2 million annually. Oversight responsibility would have to be based on expansion of present data collection, which task is more appropriately discharged under the sponsorship of governments. We estimate that expansion would cost $3 to $5 million per year. [Both of these estimates are consistent with similar ones published by the NSB Commission.]

Since no estimate exists of the value of industry's present substantial and highly diverse contributions in support of education, there is no way to even guess at the additional expenditures which would raise industry involvement in the improvement of education to a level like that contemplated by our recommendations. It should be remembered that some of these expenditures now are and presumably would be borne ultimately by the population at large through provision to the industry of tax incentives of different kinds. It is not ridiculous to set a primary target of 2 percent of cash flow, half of which, at least initially, should be earmarked for science and mathematics.

The leadership we recommend to the American Chemical Society does not have high additional costs; much of what we ask of the Society can be accomplished by reallocation at present levels of expenditure. The same is true for at least some of the programming we recommend to the Federal and State governments.

Estimate of costs to the people if there is not increased investment in quality education.

Public expenditures on education are determined by political processes. The participants in such processes seem interested in assuring that future increments in expenditure will buy a return that is significant and demonstrable. No one expects additional money to be "thrown at" education, even if that would accomplish the objectives desired by most of the people. Put plainly, some new contracts have to be written between the people and those whom they employ to educate their children. But, there are two parties to every contract and each of them, in this case, has some legitimate concerns about the expectations of the other. The negotiations must attend to both sets of concerns.

This is not the place to detail the matters to be negotiated. Those interested in them should start with the report of *The National Commission on Excellence in Education*, "A Nation at Risk," and then read: (1)"High School. A Report on Secondary Education in America," Ernest L. Boyer's elaboration of the work of the National High School Panel of the Carnegie Foundation, and (2) "Against Mediocrity: The Humanities in America's High Schools," a collection of essays edited by Chester E. Finn, Jr., Diane Ravitch, and Robert T. Fancher. In this triad of works aggregating 704 pages, the evidence is presented, the case made, and the issues laid out.

In comparison with cost *changes* that many of us regard as trivial in other areas of public expenditure, the *total* costs of improved education at all levels and in all areas are not staggering sums. Our estimates for the improvement of school science and mathematics total about $4 billion a year. That is a magnificent sum in the bank account of an individual, but it is round-off error in the aggregate of national and state budgets.

Educational improvement costs money. Failure to make educational improvement costs much more. Here we have estimated the costs of implementing the highest priority recommendations of the Task Force. We cannot estimate the costs associated with less than well-informed citizen judgements, continued low standards of teacher certification, obsolete instruction and teaching materials, failure to assist teachers to improve their qualifications or any of a host of consequences of inattention to the centrality of science in education for contemporary life; but those costs are surely very high.

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APPENDIX 4

APPENDIX

to the testimony of

DR. W. EDWARD LEAR
Executive Director

The American Society for Engineering Education

June 23, 1985

Including:

Final Report, Engineering College Faculty Shortage Project, AAES/ASEE, November, 1983

Article, "ASEE Survey of Engineering Faculty and Graduate Students, Fall 1983", Engineering Education, October, 1984

Article, "The Faculty Shortage: The 1982 Survey", Engineering Education, October, 1983

Background material/progress report, Quality of Engineering Education Project (QEEP), July, 1985

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Science Policy Task Force
U.S. House of Representatives

FINAL REPORT

ENGINEERING COLLEGE
FACULTY SHORTAGE PROJECT

AAES/ASEE

NOVEMBER 1983

EXECUTIVE SUMMARY

During the late 1970's, a few far-sighted people, mostly from the academic community, warned of serious problems descending on engineering education in the United States. They saw undergraduate enrollment climbing rapidly to new records while the number of doctorates granted in engineering were actually declining. Further, up to 40% of doctoral candidates were foreign nationals who would not practice in the U.S. Among the American Ph.D. graduates, two were employed by industry or government for each one who became a faculty member; new faculty were not even replacing attrition. At the same time, the infrastructure of engineering education - facilities and equipment - were observed to be deteriorating badly.

The "crisis" became much more visible as a result of several conferences and the report of a Presidential Commission on "Science and Engineering Education for the 1980's and Beyond". In the fall of 1980, representatives of large companies, all major employers of engineers, met informally under the leadership of Union Carbide to explore how industry could best assist schools in the renewal of the teaching and physical resources. The other companies were AT&T, DuPont, General Electric, General Motors, IBM, GTE, Exxon, and Hewlett Packard. A group of ten Presidents or engineering deans representing the broad spectrum of institutions were invited to join in the dialogue. They were from Alaska, Colorado State, Stevens, VPI, Ohio State, WPI, Iowa State, RPI, and North Carolina State. Out of this ad hoc effort came the Engineering College Faculty Shortage Project (ECFSP).

At the outset, it was clear that the faculty shortage was a result rather than the cause of problems in engineering education. However, the 4-6 year period required to "grow" Ph.D.'s prompted immediate measures to increase the number of U.S. citizens in graduate programs. It was therefore decided to focus attention and resources on that short range objective while raising awareness and organizing support for the larger issues.

The Engineering Faculty Shortage Project became operational on September 1, 1981, for a two-year period and with a budget of $100,000 per year committed by the ten sponsoring companies joined later by Rockwell International and Weinschel Engineering. A full-time Staff Executive with secretarial support was hired to manage the project. The Project was made accountable to the Executive Director of ASEE and was housed at ASEE headquarters in Washington.

An Advisory Board was empaneled which consisted of four industry people and three Deans of Engineering. The Advisory Board met nine times, and eight Progress Reports were provided to the Advisory Board and other interested parties.

Project effort and resources focused on: 1) collection of reliable data on the faculty shortage which could form bases from which conditions could be catalogued, defined, monitored and compared; 2) cataloguing the various initiatives underway or being planned to address the faculty shortage and serving as a "knowledge bank" to make these ideas available to all interested parties; and 3) keeping the public informed.

Project outputs included: Fall 1981 and Fall 1982 Surveys of Engineering Faculty and Graduate Students; Catalogs of Industry, Professional Society and State Initiatives and Programs; Fall 1981 and Fall 1982 Sampler Surveys of 32 Engineering Deans; a Survey of Tau Beta Pi Graduates of the Classes of 1977 and 1982; a report on university initiatives; a permanent reference Data Library; testimony before the House Committee on Science and Technology; in cooperation with Iowa State, a film/videotape on "Engineering Faculty for Tomorrow"; a PE-Professional Engineer article, "Gathering Up the Parts"; publication of the results of the 1981 and 1982 surveys of engineering colleges in Engineering Education; organizational participation in the National Engineering Action Conference, as well as a dozen smaller events. Interviews were given to major media resulting in national press coverage, and regular contacts with the engineering press produced on-going coverage of trends, ideas, findings and progress. Talks were given to sections, divisions, local and national meetings of more than 20 professional societies, government agencies, and private groups. More than 65 documents relating to the issues and problems impacting the faculty shortage were identified and catalogued.

Attention was paid to a variety of aspects comprising the "system" of engineering education delivery: obsolescent equipment and facilities; teaching technologies; faculty pools; coordination of effort; proliferation of disciplines; perception of engineers as a crucial national resource; development of academic management capability, among others. There is no lack of ideas for solution, but implementation is slow and hindered by resistance to change and the affinity for traditional approaches.

The "Quantitative Measures of Success" established by the Advisory Board were met, and the ECFSP effort resulted in some modest improvements in the faculty shortage situation. Decreased budgeted vacancies, improved recruitment and retention of faculty, increasing graduate enrollment, higher engineering faculty salaries, and industry and state supported programs have been reported in some cases. While these improvements are discernible, they are not substantial and erosion continues. Teaching loads and class sizes are increasing, more courses are being cancelled, and faculty research efforts are being reduced. There is still much to be done if the quality of engineering education in the U.S. is to be preserved.

INTRODUCTION

A national program to address the engineering college faculty shortage was conceived, funded, staffed and otherwise implemented for a period of two years from September 1, 1981, to August 31, 1983. This resulted from discussions held by an independent Ad Hoc Industry/Deans Group, which met at Union Carbide Headquarters in New York City on several occasions during 1980 and early 1981. The program became known as the Engineering College Faculty Shortage Project (ECFSP).

The problem was defined as a critically insufficient supply (less than 500 qualified new engineering Ph.D.'s) for more than 1600 authorized faculty openings as of the Fall of 1980 and 1981, and, in addition, a severe shortage of engineering graduate students in the pipeline for a Ph.D. degree.

The original funding organizations were AT&T; du Pont; Exxon; General Electric; General Motors; GTE; IBM; and Union Carbide. Some adjustments were made in specific company contributions, and Hewlett Packard and Rockwell International were added as sponsors during the middle of the first year. Weinschel Engineering became the eleventh sponsor during the second year of operation. The combined funding for the first year was $100,000 and $115,000 for the second year. In addition to sharing costs for two years, AT&T "loaned" the project Staff Executive* for one year and contributed heavily to support services throughout the life of the Project (clerical help; reproduction; word processing; graphics; etc.). The sponsorship organizations were the Education Affairs Council (EdAC) of the American Association of Engineering Societies (AAES) and the American Society for Engineering Education (ASEE) in Washington, D.C., the latter providing the "secretariat."

ADMINISTRATIVE ORGANIZATION

The EdAC of AAES selected an Advisory Board (first designated as a Steering Committee) to which the project Staff Executive reported. That seven-member board consisted of four people from industry and three from academe. The four industry members were selected from the college recruiting/university relations segments of the eight corporations providing the original funding, one of whom was replaced upon the occasion of his retirement. [Mr. Jerrier A. Haddad's membership (IBM) was transferred to Mr. Jack M. Grout of Hewlett Packard, which company later became a financial sponsor.] The Board's three academic members (all Deans of Engineering) were chosen to give both a geographic and a profile representation. Advisory Board membership consisted of:

---

*Mr. John W. Geils, Director, Network Departmental Administration, AT&T.

Dr. Robert K. Armstrong, Manager
Professional Staffing Section
Management Resources Division
Employee Relations Department
E. I. du Pont de Nemours & Co.
Wilmington, DE

Mr. Jack M. Grout
Corporate Manager
Educational Relations
Hewlett Packard
Palo Alto, CA

Dr. William M. Kays
Dean, School of Engineering
Stanford University
Stanford, CA

Dr. Robert H. Page
(Chairman of Advisory Board)
Dean, College of Engineering
Texas A&M University
College Station, TX

Dr. Paul V. Smith
Manager, Educational and
Professional Society Relations
Exxon Research & Engineering
Corporation
Florham Park, NJ

Mr. Robert P. Stambaugh (Retired)
Manager, University Relations
Union Carbide Corporation
Danbury, CT

Dr. Paul E. Torgersen
Dean, College of Engineering
Virginia Polytechnic Institute
and State University
Blacksburg, VA

Primary staff consisted of:

Mr. John W. Geils
Staff Executive
ECFSP
ASEE Headquarters
Washington, D.C.

Mrs. Ruth E. Geils
Administrative Assistant
ECFSP
ASEE Headquarters
Washington, D.C.

The initial meeting of the Advisory Board was held in ASEE headquarters in Washington, D.C., on September 23, 1981. Subsequent meetings were held on:

2 Feb 1982, San Diego, CA
8 Jun 1982, N.Y. City (Executive Session)
24 Jun 1982, College Sta., TX
19 Aug 1982, Wash., D.C.
26 Oct 1982, Colorado Springs, CO
2 Feb 1983, Lake Buena Vista, FL
29 Mar 1983, Hilton Head, SC
22 Jun 1983, Rochester, NY

Minutes of all sessions were sent to Board members and a group which varied from 25 to 30 people consisting of original and replacement members of the Ad Hoc Industry/Deans Group; immediate past, current and elected presidents of ASEE; the President and Chairman of AAES and the Chairman of EdAC. Progress Reports were distributed to the same roster as the Advisory Board meeting minutes and dated as follows:

October 31, 1981
December 15, 1981
January 1, 1982
February 15, 1982
April 30, 1982
May 31, 1982
October 22, 1982
March 22, 1983

PROJECT GOALS

"Aims of the Proposed Project" were set forth in the proposal dated April 29, 1981, to the eight original sponsoring companies. "Measures of Success" were developed in June 1982 by Dean Vincent Haneman of the University of Alaska's School of Engineering whom Chairman Robert H. Page designated for that task. The "priority goals" based on the "Aims" were developed by the Staff Executive, Mr. John W. Geils after several months of operation. The "Aims" were as follows:

1. to assemble and validate a body of data on supply/demand of engineers at all degree levels, which establishes the nature and extent of the engineering faculty problem.
2. to collect and disseminate information on initiatives being undertaken among industry/academe/government to alleviate the problem.
3. to actively promote a broad industry/academe involvement in programs to relieve the faculty shortage.
4. to prepare materials (brochures, presentations, press releases) which influence undergraduates and inform the public on the need for more engineering Ph.D.'s.

The "Quantitative Measures of Success" presented by Dean Haneman at the June 24, 1982, Advisory Board meeting listed four criteria:

1. An established system of quantifying data on the engineering education system will be in existence. This system will collect the data on an annual schedule. The material will be capable of verification, with established, defined and accepted terminology.
2. The results of the data collection will be published on a regular schedule in at least two engineering information systems (EMC and ASEE).
3. A catalog of activities in the area of engineering education problem identification, definition and resolution will be developed and maintained.
4. Awareness of the criticality of the problems facing engineering education will be greatly increased.
5. Long range - there will be a reduction in the unfilled faculty positions (8-10 year span).

With respect to item 1 of "Aims", an early decision was made that to attempt definitive provision of supply/demand statistics on engineering manpower would be beyond the resources of the project. Also with respect to the first part of item 4 of "Aims", the preparation of materials to influence undergraduates to take graduate work was deemed to be a potentially misguided effort until the reasons why students do not choose to become university professors were determined.* Ways and means to deliver the message to specifically interested groups which have more immediate needs to develop actions and that could influence the state of affairs was determined to be a more productive avenue. Finally, direct organization of a broad industry/academe involvement in programs to relieve the faculty shortage was avoided.

Therefore, three areas became "Priority Goals". Project effort and resources were concentrated upon:

PRODUCING DATA THROUGH SURVEYS WHICH FORM BASES FOR DRAWING CONCLUSIONS.

This area of concentration resulted in the following productions:

1. Fall 1981 Survey of Engineering Faculty and Graduate Students (A survey of about 290 engineering colleges).
2. Fall 1982 Survey of Engineering Faculty and Graduate Students
3. Catalog of State Initiatives to Aid Graduate Engineering Education
4. Catalog of Industry Initiatives to Aid Graduate Engineering Education--Issues #1, #2 and #3
5. Catalog of Professional Society Initiatives to Aid Graduate Engineering Education
6. Two "pulse-taker" Surveys of 32 Engineering Deans to monitor changes and progress: 10/81 (report dated 1/27/82); and 9/82 (report dated 11/4/82)
7. The Tau Beta Pi Survey of Student Responses: Classes of 1977 and 1982
8. Data Library (statistics, reports, papers, articles, recommendations, etc., bearing on Project-related issues from a variety of aspects).

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*The engineering deans on the Advisory Board felt that this was one of the most important questions to be asked.

TASK FORCES

Near the end of the first year of the Project (6/82), the Advisory Board decided to appoint "task forces" to assist the staff. To initiate the effort, a subcommittee of the Advisory Board was appointed, with Advisory Board Member Robert K. Armstrong as Subcommittee Chairman. By late July 1982, it was agreed to empanel task forces on:

1. **Data** (R. K. Armstrong, R. Bolz, G. Dieter, P. Doigan, D. C. Drucker, J. W. Geils, R. H. Page, S. Winkler)

   The **Data** Task Force managed the form, style, and interpretation of the Fall 1982 Survey of Engineering Faculty and Graduate Students with assistance from EMC and IBM.

2. **Industry/University Cooperative Programs**

   The **Industry/University Cooperative Programs** Task Force was asked to collect corporate initiatives from up to 500 companies for expanding the ECFSP catalog of industry programs from Issue #2 to Issue #3. The effort began as a function of the Relations With Industry Division of ASEE. It was then assigned to a committee chaired by Advisory Board Member Jack M. Grout. Neither of the approaches proved viable, and the task was finally performed by the Staff's Administrative Assistant with the help of the Council for Chemical Research and the Industrial Research Institute.

   ASEE's Deans' Council Chairman, Lionel V. Baldwin, agreed to design and circulate a survey instrument to U.S. schools of engineering aimed at determination of university initiatives similar to those from industry. The returns were analyzed by the Project staff, and a report was prepared by the Staff Executive.

3. **Communications/Publicity**

   The notion of a Communications/Publicity Task Force was abandoned in favor of asking David Novick (AAES) to explore using the Publications and Services Overview Committee (which he Chaired) of the AAES's Engineering Affairs Council as the "operating agent". This did not work out, and Advisory Board Member Robert P. Stambaugh offered to take on the task. On a short time schedule, he identified certain "publics", reported suggestions to the Advisory Board, and reviewed a number of commercial proposals.

4. **Programs of Professional Societies**

   The AAES headquarters staff assisted in solicitation of responses for the Catalog of Professional Societies Programs to Aid Graduate Engineering Education.

5. **Initiatives of the 50 states.**

   Three junior year undergraduate engineering students from Worcester Polytechnic Institute were assigned to the Project for seven weeks in the Fall of 1982, full-time, and prepared the Catalog of State Initiatives to Aid Graduate Engineering Education.

ACCOMPLISHMENTS - (Data and Dissemination)

Quantitative data were given first consideration. Two decisions were made: 1) seek a reliable existing data base, and 2) avoid statistics projected on demand for engineers. The latter was simply non-existent in 1981, and even today ELECTRONICS magazine reports "Manpower Surveys Continue to Disagree" (July 28, 1983, p. 108), citing divergent new demand projections of the American Electronics Association (AEA) and the Engineering Manpower Commission (EMC). For supply-side data, a valid data base was found: The Higher Education Panel Report No. 52, published in October 1981 by the American Council on Education and funded by the National Science Foundation. This document presented data collected in the Fall of 1980 and gave reference points against which the two major ECFSP Surveys (Fall 1981 and Fall 1982) of Engineering Faculty and Graduate Students were matched (See References 1 and 2).

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Summary of Faculty Vacancies Surveys

	1980	1981	1982
Total Faculty Positions--authorized (rounded)	16,200	18,000	18,000
Total Positions Unfilled (rounded)	1,580	1,620	1,420
% vacancies of authorized and budgeted faculty positions	9.8	9.0	7.9*
% vacant for at least one year	45.0	56.0	56.0
% vacancies of entry level, Assistant Professor	--	24.4	20.8
% faculty who left for industry/government	2.4	1.5	1.3
% industrial/government people who left to teach	--	1.4	1.4
% reporting reduction in faculty research	34.8	32.5	42.2
% reporting increase in teaching load	80.3	70.8	75.6
% unable to offer certain courses	53.5	47.5	54.5
% reporting greater reliance on graduate assistants or part-time faculty	65.7	71.7	73.3
% reporting substantial decrease in ability to recruit or retain faculty	50.8	34.4	25.4

Summary of Survey of Tau Beta Pi Students

The classes of 1977 and 1982 provided a statistical sample (see Reference 3). 1,612 responding Tau Beta Pi graduates placed stress on: a) having faculty with "practical experience"; b) being prepared in college for "real world" jobs; c) unattractiveness of graduate school because of high industry salaries compared with academe; and 3) a perception that a Ph.D. degree, in itself, does not make the faculty person a good teacher. The Tau Beta Pi graduates of the Class of '77 and Class of '82 were not parsimonious about their volunteered comments. Thirty-two comments from the Class of '77 could be grouped into a simple statement that, "Teaching would require a Ph.D. and yield a low salary and poor faculty benefits". (The full transcript of student comments is available from ASEE Headquarters.) With Tau Beta Pi graduates questioning the attractiveness of teaching, it became obvious to the Engineering College Faculty Shortage Project that steps are needed to make the faculty position much more attractive.

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*Some indications are that the state of the economy has eliminated some faculty positions which were previously unfilled. Thus this decrease is difficult to interpret.

These results of this survey provide the ingredients for a definitive look at why our best engineering students do not choose to become university professors. The 1,612 responding graduates are the cream of the crop of two significant years, 1977 and five years later 1982. Their perceptions, right or wrong, contain most of what we need to know about why students do not choose the academic profession. The two classes were chosen so as to get a "brand new" set of graduates and a set which had been out of school for five years. For the Class of 1977, 50% of the respondees started graduate study almost immediately and three-quarters of the group had received graduate degrees by the spring of 1983. However, only two percent are teaching in engineering today. Twenty-nine percent of the respondees of the Class of 1982 are now or plan soon to enroll full time in engineering graduate studies. Only seven percent of this group of recent graduates indicate teaching as a career goal. Yet, Tau Beta Pi graduates would be more likely than others to become candidates for graduate study and faculty positions. Obviously, something is wrong if our best students do not show a strong interest in engineering faculty positions.

Catalog of State Initiatives

This catalog (Reference 4) was prepared by three Worcester Polytechnic Institute engineering juniors. They were assigned to the Project full-time for seven weeks under WPI's internship plan called Interactive Qualifying Project. (Their Catalog represents September 1982 data. One should realize that changes have continued to take place due to state recognition of new programs aimed at alleviating the "crisis" in engineering education.)

The identification of existing and proposed state programs was obtained through telephone interviews with engineering deans, industry leaders, government officials and representatives of professional engineering societies. These programs were summarized and compiled into a catalog which included references for further information. A "state action matrix" indicated the range of effort made by states in addressing the faculty shortage problem. The efforts address modernizing laboratory equipment, improving faculty salaries, improving facilities, and developing "engineering centers".

One identified trend was the development of "engineering centers". Generally, the construction costs of the "centers" are funded by the state; industry is expected to equip them, and universities to staff them. Five new engineering centers (3 established, 2 proposed) focus primarily on electrical engineering and computer science. The three existing centers accounted for 45% of the total state funding identified in the catalog.

The highest level of identified state activitiy was directed at funding for laboratory equipment programs (11 implemented, 11 proposed), followed by differential faculty salary programs (8 implemented, 6 proposed). State programs that established fellowships (1 implemented, 2 proposed) for graduate students were scarce.

Catalog of Industry Initiatives

The catalog was revised twice. Three issues were published; all attracted considerable attention (Reference 5). Over 1200 copies of Issue #2 were distributed, and at least 500 copies of Issue #3 were mailed. While about 500 top corporations were asked to provide data for Issue #3, only about 40 responded. Some simply had no programs to offer; a few came in too late to make the publication cut-off date; and a surprising number of companies misdirected the request for program descriptions to their "gift and contributions" organizations which treated the request for descriptions as requests for funds. The request also went to members of the Council for Chemical Research and the Industrial Research Institute which accounted for 390 additional contacts. Other contacts were solicited by the Project staff. Issue #1 contained information on 20 programs. Issue #2 described 17 industry programs, 5 trade association program and 8 university initiatives, some in cooperation with industry. Issue #3 presented 36 industry initiatives, including five associations. The Project is now receiving unsolicited information from companies which have expressed interest in being included.

Catalog of Professional Society Initiatives

This was produced in cooperation with AAES (Reference 6). While 118 societies were contacted, very few indicated programs aimed at aiding graduate education in engineering. Many more were involved in undergraduate counselling and guidance activities.

University-Generated Initiatives Review

This was obtained through the efforts of Dr. Lionel V. Baldwin, Dean of Engineering at Colorado State University. As 1982-83 Chairman of ASEE's Engineering Deans' Council, he wrote to 311 North American members of the EDC asking their cooperation in furnishing replies to three questionnaires which he developed. The collected data were analyzed by the ECFSP and ASEE headquarters staffs and were augmented by appropriate inputs from interested faculty, the higher education press, and other sources. Twelve types of aid were rated according to their usefulness, with Unrestricted

Grants and Endowed Chairs prime choices. A large number of schools indicated participation in the industry support programs listed in Reference 5 and over one hundred companies not previously identified by the Project were listed by respondents. Most of them were of modest size, but showed significant local support of engineering schools. Research Centers in a number of geographic locations pointed to a strong academic/industry fiscal cooperative effort, sometimes arranged with the state government as a third party.

Surveys of 32 Deans

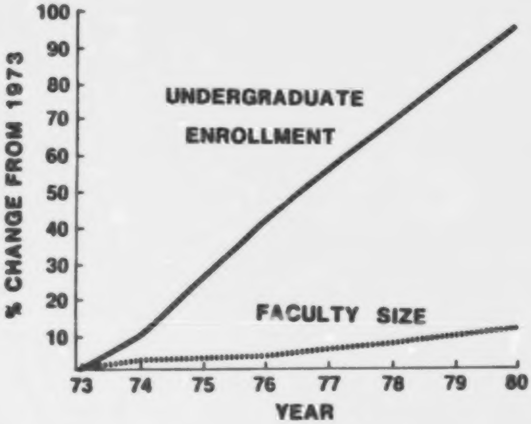
These were designed to give quick insights into feelings, actions and directions of Deans (References 8 and 9). The earlier one (Fall 1981) showed a concentration on salary issues. Also, it was reported that more money was available for larger numbers and higher salaries of graduate teaching assistants. The later one (Fall 1982) showed that steps had been taken to provide differential salary treatment for engineering faculty. Namely, 85%; 67% and 65% reported incremental increases had been obtained for assistant, associate and full professor levels, respectively. These increases were over and above normal, regularly scheduled university-wide salary adjustments. The responses also showed a utilization of non-engineering faculty, graduate students short of the Ph.D. and retirees (academic, industry or government) for engineering faculty.

The project developed a Data Library (see Reference 10) which is an assembly of germane reports, articles, brochures, papers, statistics, analyses, studies, etc. These are generously cross-indexed so that sources can be quickly identified. Two volumes are available at ASEE headquarters for review.

ACCOMPLISHMENTS - (Keeping Public Informed)

The Staff and Advisory Board missed no opportunity to tell the press of the crisis situation. FORTUNE, TIME, NEWSWEEK, The New York Times, The Chicago Tribune, The Wall Street Journal, other city newspapers, McGraw Hill publications and many trade and professional society publications were all granted interviews and urged to publicize the situation. Talks were given to diverse groups including the Department of Defense, Stanford Research Institute, the Engineering Deans' Council of ASEE, national and regional meetings of professional societies such as ASEE, AAES, NSPE, SAE and others. ECFSP material was made available to any one requesting it.

• Much of the information generated by the Project was duplicated and reproduced extensively. There was one graph that seemed to display the current status of the engineering faculty in such a descriptive way that it was reproduced in many articles and by many authors. It has been selected as the single graph to reproduce in this report and is shown below.



ENGINEERING UNDERGRADUATE ENROLLMENT VS. FACULTY SIZE
(by W. E. Lear, see Reference 1)

One of the key accomplishments of ECFSP has been the "knowledge brokerage" or "clearing house" function provided to many publics: industry, state and federal government, quasi-governmental bodies, academe, professional societies and the press. People from all sectors of the profession and from outside the profession as well came to the ECFSP office for data, advice and counsel, ideas and discussion. This national "central office" activity became a most important activity of ECFSP. Through participation in events such as the National Engineering Action Conference of April 7, 1982, and the Industry/Founder Societies Forum of January 17-19, 1982, among others, the general knowledge of the shortage and proposed solutions were amplified many times over.

As the Project concluded, requests came in daily at a sustained high level from industry, academe, and government for all sorts of information and/or data. For example, recently (in one day only) the following was handled: a small medical electronics manufacturer in Minnesota had heard there was a "crisis" and wanted to know how his firm could help; an engineering dean from a large state university visited to discuss how academe could be more effective and influential with the Congress; a major oil company house organ editor wanted comments on an article on the "crisis" which he was preparing for the company magazine going to 85,000 employees; and a major heavy electrical-generation equipment manufacturer needed data to back up an in-house report he was preparing for his CEO on the current state of engineering education, both domestic and abroad. Through these activities, many diverse but interested parties have been brought together--a good number for the very first time. This "knowledge brokerage" effort has been unique and valuable to the many publics affected by the shortage of engineering faculty.

CONCLUSIONS

The two-year national program to treat the engineering college faculty shortage made significant progress. With financial support from industry, leadership from an industry/university advisory board, and a dedicated staff; the project identified high priority goals, organized itself for action, and produced prominent results on schedule.

Quantitative data on the magnitude of the engineering faculty shortage, opinion data on the causes, and data on initiatives to provide short and long range solutions were obtained and disseminated to the interested publics and press. ASEE became recognized as a national center for engineering faculty shortage information.

Of most significance is the really basic problem that was brought into the limelight; namely, the relative unattractiveness of the engineering teaching profession. In order that the very best engineering students can be attracted to what could be prestigious faculty positions, the quality of life of the engineering faculty member must be improved. The quality of life can be improved in many ways. The most obvious are providing the engineering faculty member with a teaching load that is not backbreaking, providing the faculty with time for library and computer studies, providing modern engineering experimental facilities, and above average compensation.

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EPILOGUE

The completion of this project on schedule with goals accomplished has been the catalyst for numerous federal government/state government/industry/university actions. Of special note is the development of a new ASEE effort to follow this project entitled, "Quality of Engineering Education Project". This project headed by Dr. J. C. Hogan (former President of ASEE) continues some of the actions initiated by the ECFSP, but broadens the concerns to all issues related to the quality of engineering education.

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Diana Darnell

ASEE Survey of Engineering Faculty and Graduate Students, Fall 1983

The faculty shortage worsened at public schools, but higher salaries and better working environments improved faculty recruitment and retention.

Paul Doigan
Chairman, Engineering College Faculty Shortage Survey Committee

The questionnaire of the fall 1983 survey of engineering faculty and graduate students retained most of the questions from earlier surveys (see box) but was expanded to obtain additional information on graduate study and projections of anticipated graduates. This and the previous surveys sought, in particular, to assess the impact of faculty shortages on the quality of engineering education, determine what faculty are needed to maintain or restore quality to engineering programs, track the increase or decrease of U.S. graduate students, and identify trends in faculty recruitment and retention.

Faculty Shortages

That serious faculty shortages persist in U.S. engineering schools is confirmed by the 1983 survey. The 186 engineering schools that responded reported that 8.5 percent (1,234) of their authorized full-time faculty positions were unfilled in fall 1983, compared with 7.9 percent in fall 1982. Extended to all engineering schools, the 8.5 percent shortage would total approximately 1,570 unfilled full-time faculty positions.

The 186 engineering schools responding included over 70 percent of the public and over 50 percent of the private engineering schools. They represent nearly 80 percent of the total graduate and undergraduate enrollments in U.S. schools awarding baccalaureate or higher degrees in engineering. There were 14,550 authorized full-time faculty positions reported by these schools. Using both full-time graduate and undergraduate enrollments as the basis for extrapolation, the total number of authorized full-time faculty positions in all engineering schools is estimated to be 18,440. The distribution

About the Study

The fourth in a series of surveys on engineering faculty and graduate students was conducted in fall 1983 by the Engineering College Faculty Shortage Survey Committee of ASEE's Quality of Engineering Education project. Previous surveys were conducted by the Engineering Manpower Commission for the ASEE faculty shortage project in 1981 and 1982, and by the American Council on Education's Higher Education Panel in 1980. The 1981 findings were published in the November 1982 *Engineering Education*, the 1982 findings in the October 1983 issue.

Of the 279 questionnaires mailed in fall 1983 to deans at schools offering bachelor's or higher degrees in engineering, 186 were returned and usable (67%). ABET accreditation was not required for participation in the survey.

Members of the Engineering College Faculty Shortage Committee are: Paul Doigan (chairman), Morris Cobern, National Science Foundation, George E. Dieter, University of Maryland, and Robert H. Page, Texas A&M University. The committee appreciates the prompt response by the engineering deans and others who completed the questionnaires.

The survey was conducted with a National Science Foundation grant (SRS-8319227) and represents conditions reported in fall 1983.

Net Flow of Personnel Is From Industry/Government to Academe

▶ The number of engineers moving to academe from industry/government in 1983-84 exceeded the loss of faculty to those sectors by more than 60 percent.

of authorized full-time faculty positions and vacancies based on these enrollments are shown by discipline in table 1.

The distribution of authorized full-time engineering faculty positions reported by these schools in 1983 was not very different from that reported a year earlier; the percentage of electrical and mechanical engineering positions rose slightly.

The percentage of unfilled positions reported by public institutions increased from 8.4 percent in 1982 to 9.5 percent in 1983, while vacancies reported by private schools decreased from 6.6 percent in 1982 to 5.4 percent (table 2). With the exception of civil engineering, public schools indicated a larger percentage of unfilled positions for each of the disciplines reported. Private schools indicated fewer unfilled positions in each of the reported disciplines.

The highest percentage of unfilled positions remains at the assistant professor level at all schools, although slightly less (20%) than reported in 1982. Private schools, however, reported a much lower percentage of unfilled positions at both the assistant professor and instructor levels. Tables 3 and 4 give the distribution by rank for both public and private schools and a comparison with unfilled positions one year earlier.

Table 1. Estimated Distribution of Authorized Full-time Engineering Faculty Positions and Vacancies, Fall 1983.*

	All Schools	
Engineering Field	*Authorized*	*Vacancies*
Aeronautical & Astronautical	680	50
Chemical	1330	90
Civil	2950	150
Computer Science & Computer Engineering	1490	240
Electrical	4040	390
Industrial	990	100
Mechanical	3550	270
All other	3440	280
Total	18,440	1,570

* Extrapolated from survey data on the basis of nationwide enrollment figures.

Table 2. Unfilled Positions As Percentage of Authorized Full-time Positions, Fall 1983.

Engineering Field	*Public School*		*Private School*		*All Schools*	
Aero & Astronautical	8.9%	(6.6)	2.7%	(3.2)	7.7%	(5.8)
Chemical	8.0	(6.5)	4.9	(5.1)	7.1	(6.0)
Civil	5.6	(6.0)	3.6	(5.8)	5.2	(6.0)
Computer Sci./Engrg.	19.2	(17.9)	8.3	(14.7)	15.8	(16.8)
Electrical	11.0	(8.3)	6.0	(6.3)	9.7	(7.7)
Industrial	11.5	(9.2)	5.3	(8.9)	10.4	(9.1)
Mechanical	8.6	(8.4)	4.7	(6.5)	7.7	(7.8)
All Other	8.8	(8.3)	6.3	(4.9)	8.2	(7.4)
All Fields	9.5%	(8.4)	5.4%	(6.6)	8.5%	(7.9)

( ) 1982 survey results

Table 3. Unfilled Engineering Faculty Positions by Rank, Fall 1983.

	Public School		*Private School*		*All Schools*	
Professor	4.0%	(3.1)	2.5%	(2.4)	3.6%	(2.9)
Associate Professor	7.3	(5.3)	4.2	(3.5)	6.5	(4.8)
Assistant Professor	22.1	(22.1)	13.1	(17.7)	20.0	(20.8)
Instructor	8.1	(5.7)	2.6	(8.7)	6.9	(6.3)
All Ranks	9.5%	(8.4)	5.4	(6.6)	8.5	(7.9)

( ) 1982 survey results

Table 4. Percentage of Fall 1983 Engineering Faculty Positions Remaining Unfilled Since Fall 1982.

	Public School		*Private School*		*All Schools*	
Professor	42.8%	(48.4)	51.2%	(35.0)	44.3%	(45.1)
Associate Professor	49.2	(62.3)	20.6	(39.3)	45.0	(57.8)
Assistant Professor	52.9	(50.2)	42.0	(51.0)	51.2	(57.8)
Instructor	34.8	(69.6)	0	(22.2)	32.0	(56.2)
All Ranks	49.5%	(59.9)	39.4	(45.5)	47.9	(56.6)

( ) 1982 survey results

Shortage Persists at Public Schools and at Entry Levels

▶ The worsening of the faculty shortage—from 7.9 to 8.5 percent of authorized positions unfilled—has occurred largely at public institutions.

▶ Private schools show overall improvement but reported heavier teaching loads.

▶ Most new faculty members are hired at associate or full professor ranks, not at entry level where shortage is most severe.

Table 5. Change in Ability to Recruit and Retain Faculty, Fall 1983.

Degree of Change	*Public School*		*Private School*		*All Schools*	
Substantial Increase	3.4%	(3.0)	1.8%	(10.3)	2.8%	(5.7)
Slight/Moderate Increase	32.8	(22.2)	33.3	(34.5)	33.0	(26.8)
No Change	34.4	(15.2)	43.8	(13.8)	37.5	(14.7)
Slight/Moderate Decrease	29.4	(28.3)	21.1	(25.9)	26.7	(27.4)
Substantial Decrease	0	(31.3)	0	(15.5)	0	(25.4)
Total	100%	(100)	100%	(100)	100%	(100)

( ) 1982 survey results

Table 6. Effect of Inability To Recruit and Retain Faculty, Fall 1983.

Effect	*Public School*		*Private School*		*All Schools*	
Reduction in Research	28.6%	(47.6)	16.7%	(29.6)	25.5%	(42.2)
Increased Teaching Loads	77.1	([illegible])	75.0	(63.0)	76.6	(75.6)
Greater Reliance on Teaching Ass'ts. and/or Part-time Faculty	97.1	(80.9)	58.3	(55.6)	87.2	(73.3)
Course Not Offered	45.7	(58.7)	41.7	(44.4)	44.7	(54.4)
No Significant Effect	2.9	(6.3)	25.0	(3.7)	8.5	(5.6)

( ) 1982 survey results

Table 7. Factors to Which Improvement in Ability to Recruit and Retain Faculty Were Attributed, Fall 1983.

	Public Schools	*Private Schools*	*All Schools*
More Attractive Salaries from Regular University Resources	67.4%	85.0%	73.0%
Industry-Sponsored Programs for Enhancing Salaries	25.6	30.0	27.0
State Government Activities to Improve Funding for Engineering	20.9	5.0	15.9
Improved Faculty Environment Other than Salary	39.5	35.0	38.1
Other	23.3	25.0	23.8

The Real Engineering Faculty Shortage

▶ If based on the number of positions needed to "maintain or restore quality," the faculty shortage soars to 23 percent.

Some Improvements

▶ Both public and private schools reported more success in recruiting and retaining faculty.

▶ The percentage of unfilled faculty positions remaining vacant since the previous fall dropped from 56.6 to 47.9 percent.

Faculty Recruitment

The 1983 survey found continued improvement in recruiting and retention of engineering faculty: 35.8 percent of the schools indicated a slight, moderate or substantial increase in their ability to recruit faculty, up from 32.5 percent in 1982. As shown in table 5, public schools are still experiencing more difficulty recruiting faculty than are private schools: 29.4 percent of the public schools reported a slight or moderate decrease in their ability to hire faculty, compared to 21.1 percent of private schools.

Of the 26.7 percent of schools, public and private, that experienced a decrease in their ability to recruit and retain faculty, 25.5 percent reported a resulting reduction in faculty research, compared with 47.6 percent reporting that result in 1982. In 1983, 76.6 percent reported heavier teaching loads, about the same as in 1982, 87.3 percent reported a greater reliance on graduate teaching assistants and temporary faculty, up from 1982, and 44.7 percent reported that they were unable to offer certain courses for lack of qualified faculty members, a decrease from 1982. A larger percentage of both public and private institutions reported more reliance on teaching assistants and part-time faculty than in 1982, but only private schools reported heavier teaching loads. Both public and private schools reported less difficulty in offering specific courses than in 1982. The effects of the inability to recruit and retain faculty are summarized in table 6.

More than 73 percent of the schools attributed their improved ability to recruit and retain faculty to the more attractive salaries available from regular university resources. 85 percent of the private schools and 67.4 percent of the public schools cited this factor. A better environment for faculty, other than salary, was reported as the second most important factor by 38 percent of the respondents. Cited as contributing to a better environment were lower teaching loads, better research and laboratory equipment, renovated and expanded facilities, seed money for research, an exceptionally good accreditation visit, and faculty development leaves.

Nearly 24 percent of the schools reported other reasons for their success in recruiting and retaining faculty, including more creative and vigorous faculty recruiting, "more good Ph.D.'s available," improvement in their school's image, the tightening of the industrial job market, controlled enrollments and improvement in their reputation for research. The distribution of responses on the ability to recruit and retain faculty is summarized in table 7.

Faculty Mobility

The 150 schools that responded to the survey question on faculty mobility reported that 300, or approximately 2.1 percent of their full-time faculty, left their institutions to ac-

Table 8. Faculty Mobility, 1982-83 Academic Year.

	Public Schools	Private Schools	All Schools
Voluntarily Left for Industry/Government	254	46	300
Joined Faculty from Industry/Government	414	83	497
Tenured Positions	(308)	(75)	(383)
Non-Tenured Positions	(106)	(8)	(114)

Table 9. Tenure Status of Faculty Coming from Industry or Government, 1982-83.

	Tenured Position	Non-Tenured Position	Total
Professor	163 (42.6%)	7 (6.1%)	170 (34.2%)
Associate Professor	119 (31.1)	19 (16.7)	138 (27.8)
Assistant Professor	95 (24.8)	33 (28.9)	128 (25.8)
Instructor	6 (1.6)	55 (48.2)	61 (12.3)
Total	383 (100%)	114 (100%)	497 (100%)

cept employment in industry or government—a proportion higher at public than at private schools (table 8). These schools reported that 497 individuals left full-time positions in industry or government to join their engineering faculties. The net flow from industry and government into the universities is more pronounced than in the two previous surveys.

The attractiveness of industry and government salaries and working conditions may be a major obstacle to attracting and retaining faculty at the entry level but apparently not at higher academic ranks. More than 62 percent of the faculty positions filled by new entrants from industry or government were at the professor or associate professor rank, while only 26 percent were at the assistant professor level. Movement of faculty members to more attractive positions at other engineering schools may be a major factor in faculty retention for individual schools.

More than 77 percent of the individuals coming to the universities from industry or government entered tenured positions; almost 74 percent of these were at the rank of associate professor or professor (table 9). At public institutions, over 74 percent of these people entered tenured positions, compared with over 90 percent at private institutions.

With the exception of industrial engineering, a net gain of faculty to the engineering schools was experienced in all disciplines for which data were collected. Electrical engineering experienced the greatest influx of faculty members, a net gain more than two-and-a-half times the loss.

Production of Ph.D. Graduates

Asked about what factors would limit Ph.D. production over the next five years, respondents most frequently cited insufficient numbers of qualified applicants, insufficient funding for graduate student support, and limitations on graduate stipends (table 10). Nearly 72 percent of the schools ranked insufficient funding as the most or second most important factor. The only major difference between responses from public and private schools was on the size of graduate stipends: fewer private schools reported that as a major factor limiting Ph.D. production.

Graduate Student Characteristics

The 150 schools that submitted data on full-time graduate students reported that their fall 1983 graduate enrollment was composed of 61.9 percent U.S. students and 38.1 percent foreign national students. U.S. students accounted for 77 percent of the fellowship holders, 56.6 percent of the teaching assistantships and 57.3 percent of the research assistantships (table 11). The percentage of the research assistantships held by U.S. students increased over 1982, but the percentage of teaching assistantships and fellowship holders fell.

Public institutions were primarily responsible for the increase in total U.S. graduate student enrollment from 57.4 percent in 1982 to 61.9 percent. The survey found that each of the reported disciplines showed an increase in U.S. graduate students, with the largest in electrical (62.8 vs. 56.9 percent the previous year) and industrial (61.0 vs. 53.1 percent) engineering.

First-time enrollment of U.S. graduate students increased from 59.4 percent in 1982 to 61.8 percent in 1983. The percentage of Ph.D.-track students (52%) remained the same as in 1982, while M.S.-track students were reported to have increased from 61.6 to 64.1 percent.

Table 10. Factors* Limiting Ph.D. Production, Fall 1983.

	Public Schools	Private Schools	All Schools
Insufficient Funding for Graduate School Support	71.8%	71.9%	71.8%
Insufficient Number of Qualified Candidates	48.2	53.1	49.6
Limitations on Size of Graduate Stipends	51.8	37.5	47.9
Insufficient Facilities and Space	18.8	21.8	19.7
Insufficient Qualified Faculty	7.1	9.4	7.7
Other	3.5	3.1	3.4

*Ranked either first or second in importance.

Table 11. Percentage of U.S. Students in Graduate Student Population, Fall 1983.

	Public Schools	Private Schools	Total Schools
Teaching Assistants	57.2% (56.5)	53.5% (59.4)	56.5% (57.1)
Research Assistants	57.3 (53.4)	57.2 (58.1)	57.3 (54.8)
Fellowships	82.1 (85.7)	68.9 (72.4)	77.0 (80.2)
Other	64.5 (52.7)	57.5 (49.9)	63.5 (51.8)
All Students	62.8 (57.2)	58.4 (58.0)	61.9 (57.4)

( ) 1982 survey results.

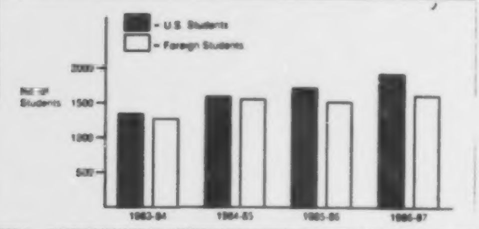
Table 12. Percentage of U.S. Students Among First-Time, Full-Time Graduate Students.

Engineering Field	M.S. Track 1981	M.S. Track 1982	M.S. Track 1983	Ph.D. Track 1981	Ph.D. Track 1982	Ph.D. Track 1983	All Students 1981	All Students 1982	All Students 1983
Aero & Astro	67.7%	73.2%	72.9%	51.8%	54.1%	50.8%	63.2%	67.0%	67.2%
Chemical	56.6	63.2	67.6	54.4	53.6	56.8	57.4	60.1	67.4
Civil	55.2	57.0	60.1	44.6	44.4	49.4	53.2	54.6	57.5
Computer Sci./Engrg	63.0	61.1	57.3	58.2	55.3	54.3	62.2	61.9	58.3
Electrical	62.8	61.8	66.4	48.7	49.5	49.6	59.4	60.1	62.4
Industrial	5. 3	57.1	64.5	45.6	48.9	42.0	54.0	55.1	61.2
Mechanical	61.J	60.1	66.0	43.2	42.5	41.8	58.8	56.7	61.8
All Fields	60.1	61.6	64.1	48.5	52.0	52.0	57.6	59.4	61.8

Table 13. Graduate Student Stipends,* Fall 1983.

	Public Schools		Private Schools		All Schools	
A–Teaching Assistants	*High*	*Average*	*High*	*Average*	*High*	*Average*
First Year	$6,833	$5,523	$5,074	$4,642	$6,448	$5,319
Second Year	7,348	6,040	5,122	4,786	6,846	5,750
Third Year and Beyond	8,236	6,640	5,636	5,350	7,561	6,325
B–Research Assistants						
First Year	$7,637	$6,004	$5,783	$5,209	$7,247	$5,576
Second Year	7,670	6,309	6,250	5,359	7,349	6,087
Third Year and Beyond	9,052	6,584	6,831	5,860	8,510	6,353

*Net for 20 hours/week during academic year, excluding tuition and fees paid by student



F   I *Projections of engineering Ph D graduates*

Graduate Student Trends

- **Full-time enrollment of U.S. graduate students has risen for the past three years.**
- **The percentage of Ph.D.-track students who were U.S. citizens remained the same as in 1982.**
- **The percentage of research assistantships held by U.S. students increased over 1982, but the percentage of U.S. teaching assistantships and fellowship holders fell.**
- **The percentage of U.S. citizens enrolled in computer science/engineering dropped for the third year.**

At the master's level, increases in first-time full-time enrollments of U.S. students were reported in chemical, civil, electrical, industrial and mechanical engineering (table 12). For the third year, computer science/computer engineering recorded decreases in the percentage of first-time U.S. students enrolled. At the doctoral level, increases in first-time full-time enrollment were reported only in chemical and civil engineering.

The survey included a new question on the anticipated increase in the number of Ph.D. graduates over the next three years. Extrapolating these projections based on graduate enrollment to the total engineering school population, it is estimated that the number of Ph.D. graduates will increase to over 3,600 by 1987 (figure 1). The percentage of U.S. graduates is expected to account for over 54 percent of the total.

As reported earlier, limits on the size of graduate stipends were cited as being a serious obstacle to increasing the number of Ph.D. graduates. At private institutions, where tuition and fees are higher, the average net stipends paid to both teaching and research assistants were lower than at public institutions. The average of the high figures ($7,472 vs. $5,278) shows an even greater spread between the public and private schools. A look at the current net stipends (excluding tuition and fees paid by the student) as reported by 150 of the schools that offer graduate programs is given in table 13.

Quality of Engineering Education

Last year, more than 85 percent of

Table 14. Size of Sections in Junior/Senior Classes, Fall 1983.

	Public Schools	*Private Schools*	*All Schools*
Substantial Decrease	0.8%	1.7%	1.1%
Slight Decrease	11.8	11.7	11.7
No Change	37.0	35.0	36.3
Slight Increase	37.8	45.0	40.2
Substantial Increase	12.6	6.7	10.6

Table 15. Authorized Faculty Positions As Percent of Number Needed to Maintain or Restore Quality, Fall 1983.

	Public Schools	*Private Schools*	*All Schools*
Professor	92%	100%	94%
Associate Professor	82	95	85
Assistant Professor	83	83	87
Instructor	83	98	86
All Ranks	80%	95%	84%

Table 16. Faculty Shortage Based on Need to Maintain or Restore Quality, Fall 1983.

	Public Schools	*Private Schools*	*All Schools*
Professor	10.7%	0.6%	8.5%
Associate Professor	23.3	8.6	20.3
Assistant Professor	50.2	27.8	45.8
Instructor	22.9	4.5	19.5
All Ranks	26.7%	10.1%	23.2%

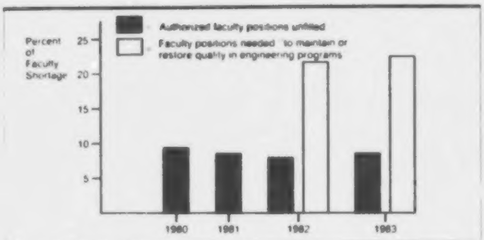


Figure 2 Faculty shortages

the engineering deans responding to a question on the quality of engineering education expressed concern and noted that student/faculty ratios were increasing. The average enrollment in a typical junior or senior class was reported in 1982 to have increased up to 56 percent since 1977. Following up on this question, the current survey found that more than 10 percent of the responding schools had experienced a substantial increase in the size of sections in junior and senior classes (table 14). More public than private schools reported this condition. A slight or substantial increase in class size was reported by more than half of the responding schools, while less than 13 percent reported a slight or substantial decrease in class size.

The Real Faculty Shortage

When the need for engineering faculty was questioned in terms of the number required "to maintain or restore quality in your programs," engineering deans reported that their authorized full-time faculty strength is less than 84 percent of the number required (table 15). This translates into nearly 22,000 full-time faculty needed in the nation's engineering schools, and a "real" faculty shortage of over 23 percent rather than the 8.5 percent shortfall reported on currently authorized positions.

This is the second year that data on faculty needed to maintain or restore quality have been collected. The two-year trend, along with four years of data on authorized positions, is shown in figure 2. Further evidence of the plight of the public schools is revealed in table 16. Public schools report a "real" faculty shortage of nearly 27 percent, compared to slightly more than 10 percent at private schools.

Paul Doigan, chairman of the ASEE Engineering College Faculty Shortage Survey Committee, recently retired from the General Electric Company after 34 years. He has long been active in ASEE, serving as chairman of the College-Industry Council and the Relations With Industry Division and as a member of the Board of Directors. The immediate past-chairman of the Engineering Manpower Commission, he is engaged in consulting on education, manpower and immigration problems.

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The Faculty Shortage: The 1982 Survey

While slightly fewer positions are reported vacant, the ill effects of the shortage are being felt more severely by both faculty and students.

John W. Geils
Staff Executive
Engineering College Faculty Shortage Project

Faculty shortages continue to be a problem for our engineering schools. That fact is confirmed by the second survey of faculty and graduate students conducted by the Engineering College Faculty Shortage Project (see box). The 1982 questionnaire, mailed to 286 engineering deans, was expanded to gather information on the use of graduate students, adjunct and affiliate professors, and on quality factors. In particular, the survey sought to 1) assess the impact of faculty shortages on the quality of engineering education, 2) determine the additional faculty needed to maintain or restore quality to engineering programs, 3) track the increase or decrease of U.S. graduate students, and 4) identify areas of engineering expertise in which it is most difficult to recruit faculty.

The following report of the findings is based on a summary prepared by Paul Doigan and P.J. Sheridan of the Engineering Manpower Commission.

Faculty Positions—Authorized and Unfilled

The 160 schools reported in this survey include nearly 60 percent of the public engineering schools and over 50 percent of the private ones, and they represent approximately 70 percent of total engineering graduate and undergraduate enrollments. These schools reported over 12,300 full-time faculty positions were authorized for fall 1982. The figure for all engineering schools, calculated on the basis of enrollment numbers, is estimated to be approximately 18,000 authorized full-time positions. The distribution of these positions by discipline and type of institution in fall 1982 (table 1) is not significantly different from that reported in 1981. (Because the 1982 survey attempted to better differentiate computer science/computer engineering from electrical engineering, the percentage of authorized positions shown for computer science/computer engineering has risen, with a comparable decrease shown for electrical engineering.)

The engineering schools reported 200 fewer unfilled positions in 1982: 7.9 percent of their authorized full-

About the Survey

Results of the 1981 Survey of Engineering Faculty & Graduate Students were presented, analyzed and discussed in *Engineering Education* last November.* The advisory board of the Engineering College Faculty Shortage Project agreed that the survey should be repeated in the fall of 1982. The questionnaire was substantially expanded by a data task force empanelled for that purpose and consisting of three deans—George Dieter of Maryland, Ray Bolz of Worcester Polytechnic and Robert Page of Texas A&M—plus Paul Doigan of the Engineering Manpower Commission, Stanley Winkler of IBM and Jack Geils of the ECFS project, under the chairmanship of Robert Armstrong of DuPont.

At the request of ECFSP, the Engineering Manpower Commission prepared the questionnaire and mailed it on November 15, 1982, to 286 engineering deans at schools offering bachelor's or higher degrees in engineering. ABET accreditation was not required for participation.

Response was slow. A follow-up letter and telephone calls in January 1983 resulted in 160 usable replies (56%), not quite as high as last year's 194 replies (68%)

All are grateful to IBM, which volunteered to perform the necessary computer programming and data processing.

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*"The Faculty Shortage: A Review of the 1981 AAES/ASEE Survey," Nov. 1982, pp. 147-153.

Table 1. Distribution of Authorized Full-Time Engineering Faculty Positions, Fall 1982.

Engineering Field	*Public Schools*		*Private Schools*		*All Schools*	
Aero & Astronautical	4.8%	(4.4)	3.7%	(3.3)	4.5%	(4.1)
Chemical	8.0	(7.9)	8.8	(8.9)	8.5	(8.4)
Civil	18.0	(17.4)	14.3	(14.8)	17.0	(16.7)
Computer Sci./Engrg.*	6.4	(4.9)	8.6	(4.1)	7.1	(4.7)
Electrical*	20.2	(22.0)	23.0	(27.3)	21.0	(23.5)
Industrial	6.5	(5.4)	4.7	(3.4)	6.0	(4.8)
Mechanical	17.7	(18.7)	18.6	(21.3)	17.9	(19.5)
All Other	18.4	(19.3)	17.3	(15.7)	18.0	(18.2)
All Fields	100%	(100)	100%	(100)	100%	(100)

*Some of the rise in computer sci./engrg. and fall in electrical engrg. results from a clearer differentiation of these fields in the 1982 survey.

( ) 1981 survey results

Table 2. Unfilled Positions as Percentage of Authorized Full-time Positions, Fall 1982.

Engineering Field	*Public Schools*		*Private Schools*		*All Schools*	
Aero & Astronautical	6.6%	(5.9)	3.2%	(2.6)	5.8%	(5.1)
Chemical	6.5	(9.0)	5.1	(8.2)	6.0	(8.8)
Civil	6.0	(8.7)	5.8	(6.8)	6.0	(8.2)
Computer Sci./Engrg.	17.9	(17.0)	14.7	(16.8)	16.8	(17.0)
Electrical	8.3	(8.8)	6.3	(7.9)	7.7	(8.5)
Industrial	9.2	(11.6)	8.9	(11.8)	9.1	(11.6)
Mechanical	8.4	(9.5)	6.5	(7.6)	7.8	(8.9)
All Other	8.3	(9.3)	4.9	(7.2)	7.4	(8.8)
All Fields	8.4	(9.5)	6.6	(7.9)	7.9	(9.0)

( ) 1981 survey results

Faculty Shortages Show Improvement

▶ 7.9% of authorized full-time engineering faculty positions were unfilled as of fall 1982—down from 9.0% reported for 1981.

▶ 56% of fall 1982 vacancies had been unfilled one year earlier—the same as reported for 1981.

▶ 20.8% of assistant professor positions were unfilled—down from 24.4% in 1981.

▶ 32.5% of institutions reported an increase in their ability to recruit and retain faculty—up from 16.5% in 1981.

time faculty positions were unfilled compared to 9.0 percent reported for fall 1981—an estimated 1,400 vacancies compared to 1,600. Of these unfilled positions in fall 1982, 56.6 percent were reported vacant in fall 1981; in 1981, 56.1 percent of the unfilled positions had been vacant one year earlier. The vacancy rate at public schools was slightly higher than at private schools, as shown in table 2. Although the total number of vacancies is small compared to the other disciplines, aeronautical and astronautical engineering reported a greater percentage of unfilled positions at both public and private schools than last year. Public schools reported a greater percentage of unfilled computer science/computer engineering positions.

As in 1981, the greatest percentage of unfilled positions was at the assistant professor level, where an overall vacancy rate of 20.8 percent was reported—22.1 percent at public schools and 17.7 percent at private schools (see tables 3 and 4). The overall vacancy rate is down from the 24.4 percent reported in 1981.

In response to the question about areas of engineering expertise in which it was most difficult to recruit faculty and the number of openings in these areas, computer science/computer engineering (with 164 positions) and robotics and CAD/CAM (94 positions) led the list, followed by electronics/microelectronics/VLSI design, electric power/power systems/energy systems, petroleum/mining/geological engineering, and chemical processing/chemical engineering. A total of 140 schools reported 600 openings in the difficult-to-fill areas.

Table 3. Unfilled Engineering Faculty Positions, by Rank, Fall 1982.

	Public Schools		*Private Schools*		*All Schools*	
Professor	3.1%	(3.7)	2.4%	(2.6)	2.9%	(3.4)
Assoc. Prof.	5.3	(7.1)	3.5	(4.4)	4.8	(6.4)
Ass't. Prof.	22.1	(24.9)	17.7	(23.6)	20.8	(24.4)
Instructor	5.7	(13.2)	8.7	(2.5)	6.3	(10.9)
All Ranks	8.4	(9.5)	6.6	(7.9)	7.9	(9.0)

( ) 1981 survey results

Table 4. Percentage of Fall 1982 Unfilled Positions Remaining Unfilled Since Fall 1981.

	Public Schools		*Private Schools*		*All Schools*	
Professor	48.4%	(58.5)	35.0%	(54.5)	45.1%	(57.6)
Assoc. Prof.	62.3	(57.9)	39.3	(37.1)	57.8	(54.1)
Ass't. Prof.	60.2	(60.1)	51.0	(47.6)	57.8	(56.4)
Instructor	69.6	(54.2)	22.2	(33.3)	56.2	(53.2)
All Ranks	59.9	(58.8)	45.5	(47.3)	56.6	(56.1)

( ) 1981 survey results

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Faculty Shortages Worse in Specialized Areas

- ▶ Over 160 faculty vacancies reported in computer science and computer engineering.
- ▶ Over 90 faculty vacancies reported in robotics and CAD/CAM.

Table 5. Change in Ability to Recruit and Retain Faculty, Fall 1982.

Degree of Change	*Public School*		*Private Schools*		*All Schools*	
Substantial Increase	3.0%	(4.9)	10.3%	(5.8)	5.7%	(5.3)
Slight/Mod. Increase	22.2	(6.9)	34.5	(17.6)	26.8	(11.2)
No Change	15.2	(5.9)	13.8	(22.1)	14.7	(12.4)
Slight/Mod. Decrease	28.3	(40.2)	25.9	(32.9)	27.4	(37.1)
Substantial Decrease	31.3	(42.2)	15.5	(22.1)	25.4	(34.1)
	100%	(100)	100%	(100)	100%	(100)

( ) 1981 survey results

Table 6. Effects of Inability to Recruit and Retain Faculty, Fall 1982.

Effect	*Public Schools*		*Private Schools*		*All Schools*	
Reduction in Research	47.6%	(33.7)	29.6%	(29.7)	42.2%	(32.5)
Increased Teaching Loads	80.9	(75.9)	63.0	(59.5)	75.6	(70.8)
Greater Reliance on Teaching Ass'ts. and/or Part-Time Faculty	80.9	(75.9)	55.6	(62.2)	73.3	(71.1)
Course Not Offered	58.7	(47.0)	44.4	(48.6)	54.4	(47.5)
No Significant Effect	6.3	(4.8)	3.7	(8.1)	5.6	(5.8)

( ) 1981 survey results

Table 7. Engineering Faculty Characteristics, Fall 1982.

Characteristic	*Public Schools*		*Private Schools*		*All Schools*	
Tenured	73.0%	(67.9)	66.1%	(61.8)	71.1%	(66.1)
Have Doctorate	85.5	(80.4)	88.0	(81.8)	86.4	(80.8)
Non U.S. B.S. Degree	17.3	(16.6)	19.9	(19.2)	18.0	(17.4)
Own Ph.D. Graduate	12.5	(17.9)	15.4	(18.2)	13.3	(18.0)

( ) 1981 survey results

Faculty Recruitment

The 1982 survey reports some improvement in recruiting and retaining engineering faculty: 32.5 percent of the schools responding indicated a slight, moderate or substantial increase in their ability to recruit faculty, up from the 16.5 percent who reported an increased ability in 1981 and the 12 percent reported in 1980.* As shown in table 5, public schools are still having more trouble recruiting faculty than are the private schools: 25.2 percent of the public schools reported a slight, moderate or substantial increase in their ability to hire faculty, compared to 44.8 percent of the private schools. Nevertheless, these numbers show a substantial improvement for both groups over 1981. The three-year trend is shown in figure 1.

How has difficulty in recruiting faculty affected the schools? Of the schools that experienced a slight, moderate or substantial decrease in their ability to recruit and retain faculty, the majority reported heavier teaching loads (76.6%), more reliance on graduate teaching assistants or temporary faculty (73.3%) and inability to offer certain courses for lack of qualified faculty members (54.4%), while a substantial minority reported a reduction in faculty research (42.2%). As shown in table 6, a greater percentage of both public and private institutions reported an increase in teaching loads over 1981, but the other effects reportedly increased only at the public schools.

Faculty Characteristics

The 1982 survey data show that over 71 percent of all full-time engineering faculty members hold tenured positions; more than 86 percent have doctorates; 18 percent did not receive their B.S. degrees from an institution in the United States; and over 13 percent received their Ph.D. degrees from the institution at which they are now employed (table 7). The highest percentage of tenured faculty, as shown in table 8, was reported in aeronautical and astronautical engineering, the lowest in computer science/computer engineering. Chemical engineering reported the highest percentage of faculty with Ph.D. degrees. The highest percentage of foreign-born faculty is in computer science/computer engineering (20.7%). Employment of a school's own Ph.D. graduates is highest in

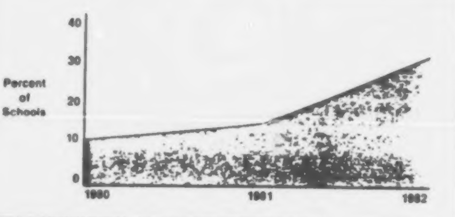

Figure 1. Increase in ability to recruit faculty.

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*Higher Education Panel Survey No. 52, American Council on Education, Wash., D.C., 1980.

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Effect of Faculty Shortages Becomes More Severe

- ▶ 42.4% of institutions report a reduction in faculty research—up from 32.5% in 1981.
- ▶ 75.6% of institutions report increased teaching loads—up from 70.8% in 1981.
- ▶ 73.3% of institutions report greater reliance on teaching assistants and part-time faculty—up from 71.7% in 1981.
- ▶ 54.4% of institutions report that courses cannot be offered in some subjects—up from 47.5% in 1981.

Table 8. Engineering Faculty Characteristics by Discipline, Fall 1982.

Engineering Field	*Tenured*	*Have Doctorate*	*Non U.S. B.S. Degree*	*Own Ph.D. Graduate*
Aero & Astronautical	73.0%	84.4%	16.9%	13.6%
Chemical	69.8	96.0	18.9	9.3
Civil	69.5	85.7	19.8	12.2
Computer Sci./Engrg	55.6	89.2	20.7	12.4
Electrical	70.8	86.8	19.2	15.0
Industrial	64.0	83.1	18.9	9.7
Mechanical	69.4	84.2	18.7	10.7
All Other	81.8	86.5	12.3	12.8
All Fields	71.1	86.4	18.0	13.3

Table 9. Faculty Mobility, 1981-1982.

	Public Schools		*Private Schools*		*All Schools*	
Voluntarily Left for Industry/Government	173	(211)	54	(55)	227	(266)
Joined Faculty from Industry/Government	179	(161)	73	(90)	252	(251)
Tenured Positions	139		65		204	
Non-Tenured Positions	40		65		204	

(   ) 1981 survey results

electrical engineering and lowest in chemical engineering.

Faculty Mobility

The 126 schools responding to the question on faculty mobility reported that 227, or approximately 1.8 percent, of their full-time faculty left their institutions to accept employment in industry or government. At the same time, these schools reported that 252 individuals left full-time positions in industry or government to join their engineering faculties, and 204 of them entered tenured or tenure-track positions. Since the net flow is into the universities, it might be concluded that the attractiveness of industry or government salaries and working conditions is not the major cause of the inability of engineering schools to retain faculty. The movement of faculty members to more attractive positions in other engineering schools is undoubtedly a greater factor in the faculty retention problem for individual schools.

Table 9 shows mobility data reported by 126 respondents compared with the 1981 data reported by 137 schools. With the exception of computer science/computer engineering and industrial engineering, a net gain to the engineering schools was experienced in all disciplines for which data were collected. Computer science/computer engineering and industrial engineering departments in the public schools were most affected by the loss of faculty members.

Faculty Salaries

Academic year (9-10 month basis) salary information was requested for all faculty members excluding administrators and department heads. The highest salary was reported by a public institution. Salaries of professors were reported at a high of $70,000 and an average of $37,800. The highest associate professor salary was $48,500 and the average was $32,180, while the highest assistant professor salary was $46,600, the average, $26,400. Although the top salary in each of the three ranks was reported by public institutions, on the average salaries paid by private institutions were higher at all academic ranks (table 10). The "all schools" salaries are up from last year by 7.1 percent for professors, 10.7 percent for associate professors and 11.0 percent for assistant professors, compared to a 6.5 percent increase for all higher education.

Graduate Student Characteristics

In fall 1982, the 113 schools that submitted data on full-time graduate

Industry & Government May Not Be Major Factors in Faculty Retention

- ▶ Both public and private institutions report the flow of new faculty members into their institutions is greater than their loss to industry/government.

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Table 10. Engineering Faculty Salaries (Avg. on 9-Month Basis).

	Public Schools	*Private Schools*	*All Schools*	*Range*
Professor	$37,500 (35,530)	$38,300 (34,980)	$37,800 (35,320)	$70,700-21,150 (64,700-20,000)
Associate Professor	29,900 (26,230)	30,600 (27,890)	30,180 (26,100)	48,500-17,850 (45,350-16,000)
Assistant Professor	26,200 (24,040)	26,700 (24,110)	26,400 (24,080)	46,610-16,935 (35,860-12,720)

(   ) 1981 survey results

Table 11. Percentage of U.S. Students in Graduate Student Population, Fall 1982.

	Public Schools		*Private Schools*		*Total Schools*	
Teaching Assistants	56.5%	(59.1)	59.4%	(59.9)	57.1%	(59.3)
Research Assistants	53.4	(57.8)	58.1	(60.4)	54.8	(58.8)
Fellowships	85.7	(74.4)	72.4	(68.9)	80.2	(71.5)
Other	52.7	(67.1)	49.9	(72.4)	51.8	(68.8)
All Students	57.2	(63.4)	58.0	(66.6)	57.4	(64.5)

(   ) 1981 survey results

students reported enrollments of 57.4 percent U.S. students and 42.6 percent foreign nationals. U.S. students accounted for over 80 percent of the fellowship holders, and more than half of the teaching research assistantships. While the percentage of fellowships held by U.S. students rose from 1981 to 1982, the percentage of assistantships fell (table 11).

By discipline, the lowest percentages of U.S. graduate students were reported at 44.1 percent for civil and 45.1 percent for industrial engineering (both in private schools), and the highest for aeronautical and astronautical engineering at 65.2 percent in private schools, and computer science/engineering at 63.9 percent in public schools.

In an effort to track the trend in enrollment of U.S. and foreign-national graduate students, the survey requested information on first-time, full-time graduate student enrollments for both fall 1981 and fall 1982. Subsequent surveys will extend this data base.

First-time enrollment of U.S. graduate students increased slightly from 57.6 percent in 1981 to 59.4 percent in 1982. The number of students pursuing the Ph.D. increased over 3.5 percent in this period, while the number of M.S.-track students was reported to have increased somewhat less (table 12).

At the M.S. level, first-time, full-time enrollment of U.S. students was reported to have increased from fall 1981 to fall 1982 in aeronautical and astronautical (by 5.5%), chemical (4.6%), civil (1.8%) and industrial (0.8%) engineering. The percentage of such enrollment declined in computer science/computer engineering (by 1.9%), mechanical (1.7%), and electrical (1.0%) engineering. At the Ph.D. level, first-time, full-time enrollment increases were reported only for industrial (3.3%), aeronautical and astronautical (3.0%) and electrical (0.9%) engineering.

There has been much speculation over the time required to complete a Ph.D. degree program in engineering. As reported by 108 schools, the average time engineering students take to obtain a Ph.D. ranges from 4.4 years for chemical engineers at public schools to 5.4 years for industrial engineers at private schools. In all disciplines, students at private institutions required more time—an average of eight months longer—to complete a Ph.D. program than those at public institutions (table 13).

The survey also found that on the average, less than half (48.9%) of all first-time, full-time enrolled graduate students complete the Ph.D. program. The highest completion rate was 72.5 percent for industrial engineering at private institutions, and the lowest was 44.1 percent for electrical engineering and aeronautical and astronautical engineering at public schools.

Quality of Engineering Education

Over 87 percent of the engineering deans responding agreed that there is concern that the quality of engineering education has suffered because of higher student/faculty ratios and other factors associated with increased undergraduate enrollments. Evidence of the concern was

Table 12. First-Time, Full-Time Graduate Students.

	1981	*1982*
M.S. Track		
U.S.	60.1%	61.6%
Foreign Nationals	39.9	38.4
Ph.D. Track		
U.S.	48.5	52.0
Foreign Nationals	51.5	48.0
All Students		
U.S.	57.6	59.4
Foreign National	42.4	40.6

Table 13. Average Time to Complete Ph.D.

Engineering Field	*Public School*	*Private School*	*All Schools*
Aero & Astronautical	4.6 years	4.9 years	4.7 years
Chemical	4.4	4.5	4.4
Civil	5.0	4.9	5.0
Computer Sci Engrg	4.8	5.1	4.9
Electrical	4.7	5.2	4.9
Industrial	4.5	5.4	4.7
Mechanical	4.8	5.2	4.9
All Fields	4.6	5.3	4.8

U.S. Graduate Student Trends

- **Total percentage of U.S. graduate student enrollment in 1982 decreased from 1981.**
- **Percentage of *first-time, full-time* U.S. graduate student enrollment in 1982 increased.**
- **Average time to complete a Ph.D. degree program in engineering is 4.8 years.**
- **About 50 percent of new graduate students complete the Ph.D. in engineering.**

given in the more than 150 responses to the question, "*In what ways do you feel the quality has been most severely eroded*? A sampling of the responses:

"Interpersonal relationships between faculty and students are declining rapidly. Teaching effectiveness is declining as class size increases. Less-qualified part-time faculty use is increasing."

"Increased student/faculty ratio has reduced the amount of guidance and direction that can be given a student on an individual basis both in and out of the classroom."

"Heavier teaching loads, less time for research and personal professional development, reduced budgets for supplies and equipment. Faculty is generally overworked!"

"Budgetary resources have fallen far behind needs to serve increased enrollments; faculty do not have time for student contacts or the time needed for research and professional development."

"Faculty do not have time to prepare grant proposals, write journal articles or books, do research, meet with students for relaxed discussions. Faculty are being burned out."

Although all segments of the undergraduate student population appear to be affected, the high achievers and the educationally disadvantaged seem most affected by these problems. Consider this sampling of comments from concerned engineering educators:

"Minorities tend to suffer more since most of them need more counseling and guidance."

"Both high achievers and low achievers are being affected adversely because of insufficient time for personal contact with faculty; the former cannot be sufficiently challenged and the latter cannot be adequately helped."

"High achievers are probably the most affected, but all segments are very seriously adversely affected."

"Due to decreased contact, high achievers suffer as fewer advanced projects are available. At the other end of the scale, it is more difficult to give special attention to those who are educationally disadvantaged upon arrival."

A quantitative measure of the erosion of quality is given by the response to the survey question concerning the section size of professional/design courses. Respondents were asked to give estimates of "worst case" and "typical case" section sizes for fall 1977 and fall 1982. As shown in table 14, over the past five years enrollment in senior-level professional/design courses and laboratories has risen sharply. The average enrollment in a typical class increased by up to 56 percent, while the average "worst case" class size increased by up to 73 percent. On the average, "worst case" class size ranged up to 81 percent greater than typical classes reported in the same year. The "worst case" class sizes were as high as 120 to 205 in 1982, up from 100 to 154 in 1977.

Classes have grown larger in both private and public institutions. Private schools reported slightly smaller average class sizes than public schools in 1982 for "typical case" senior-level professional, design and project courses (overall 26.6 vs. 32 students) while laboratory class sizes average the same at both types of institution—24 students.

Another Look at the Faculty Shortage

Although the deans reported a 7.9 percent shortfall from their autho-

Faculty Shortages Affect Quality of Engineering Education

- **"Faculty are falling behind because of inadequate research."**
- **"Both high achievers and low achievers are being affected adversely because of insufficient time for personal contact with faculty."**
- **Typical class sizes for senior-level professional and design courses rose by 41-56% over past five years.**
- **When measured by the deans' perception of how many faculty are needed to maintain or restore quality in engineering programs, the shortage is nearly three times that based on authorized positions alone.**

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Table 14. Change in Size of Section Enrollments, 1977 and 1982.

	"Typical Case" Class Size				"Worst Case" Class Size			
	1977		1982		1977		1982	
	Average	High	Average	High	Average	High	Average	High
Senior Level Professional	23	60	36	165	37	154	64	187
Senior Level Design	22	53	32	80	32	120	40	151
Senior Level Project	16	100	23	120	23	100	33	120
Junior/Senior Laboratory	17	70	24	100	24	121	36	205

rized full-time faculty strength, many thought the faculty shortage was actually much larger. The 1982 survey asked how many faculty positions were needed to maintain or restore quality to engineering programs. Deans from 160 engineering schools reported that their authorized full-time faculty strength was only 84.8 percent of the strength they think is needed. This would translate into a perceived faculty shortage of 21.9 percent, almost three times larger than the 7.9 percent calculated from the authorized positions. This perceived shortage was reported to be 24.3 percent at public institutions and 14.8 percent at private institutions.

John W. Geils is staff executive of the Engineering College Faculty Shortage Project at ASEE. He is retired from AT&T Co., where he was director of Network Department administration. During 23 years at Bell Telephone Laboratories, he performed R&D on telephone transmission and military electronics systems, and became assistant vice president of the Systems Engineering Department. Mr. Geils holds a B.E.E. degree from Rensselaer Polytechnic Institute and has attended Columbia University graduate school and Williams College advanced management programs.

Are These on Your Shelf?

The Teaching of Elementary Problem Solving

First published in 1980, this compendium on how to teach problem solving has been revised and expanded to include a chapter by Fred Reif (UC Berkeley) on information processing. The editor sums up the book's approach: "The teaching of abstract reasoning and logical thinking is a difficult exercise in human psychology. An enormous variety of approaches is possible and relevant. Some of the suggestions will strike a responsive chord in some teachers and repel another. But collectively, all the papers do offer enough patterns, procedures, templates and ideas to help most teachers start exploring and experimenting with their own courses."

The Teaching of Elementary Problem Solving in Engineering and Related Fields, edited by J.L. Lubkin, 1980 second edit., 1981, 13 chapters, 197 pp., paperbound, $10

Engineering—Images for the Future (Annual Conference Proceedings)

New technologies and their effect on teaching and curricula, plus new ways to develop industry/university cooperation were among the many issues examined at the 1983 ASEE Annual Conference at RIT. If you were unable to attend the Conference, part of it can come to you through the Proceedings. The three-volume set, bound in soft covers, contains approximately 260 papers not available elsewhere. The Proceedings will be a valuable addition to your school or personal library.

1983 ASEE Annual Conference Proceedings, edited by L.P. Grayson and J.M. Biedenbach; 1,248 pp., softbound, 3 vols., $40/members, $45/non-members. (If not prepaid, a $3.00 charge for postage and handling will be added.)

A Response to Advancing Technologies: Repositioning Engineering Education to Serve America's Future

This volume concisely summarizes and discusses 21 papers from industry, government and education leaders, commissioned with NSF funding. The authors look at advancing technologies and their impact on social and economic productivity, design practices, and engineering curricula and teaching. Chapters cover: technology's impact on society, productivity and improvement with computers, solutions—and problems—from government, computer-aided engineering in industry, the delivery of engineering education through technology, education programs using CAE and CAM, and the prognosis for the future.

A Response to Advancing Technologies: Repositioning Engineering Education to Serve America's Future; [illegible] 76 pp., $4.00 prepaid.

Copies are available from ASEE Publication Sales, Suite 200, Eleven Dupont Circle, Washington, D.C. 20036.

QUALITY OF ENGINEERING EDUCATION
PROJECT
OF THE
AMERICAN SOCIETY FOR ENGINEERING
EDUCATION

W. E. Lear, Director

Background of

The ASEE Quality of Engineering Education Project (QEEP)

In September, 1983, the Engineering College Faculty Shortage Project (ECFSP), a two-year effort funded by industry, concluded its work. The project achieved its primary objectives of (1) developing reliable data on the severity of the shortage of faculty in the nation's engineering colleges, (2) creating broad public awareness of the problems of engineering education, (3) encouraging a variety of initiatives by industry, local and federal government, and by the universities to address the faculty shortage problem, and (4) serving as a clearinghouse of information about these initiatives.

It was recognized at the time the ECFSP was initiated that the task of "refilling the pipeline" to insure adequate numbers of qualified faculty for the engineering colleges could not be accomplished in two years. In the proposal to the industrial sponsors of the project, ASEE therefore signified its intent to carry on appropriate parts of the work following the two-year project lifetime. The Board of Directors of the Society reaffirmed that intent early in 1983, but further directed that the continuing effort be broadened to include all those factors which affect the quality of engineering education, adequate numbers of qualified faculty being only one of them. This program was labeled the Quality of Engineering Project (QEEP).

An advisory committee was established for QEEP and charged with developing an agenda for the project. Following several meetings, the committee produced a comprehensive proposal, "Excellence in Engineering Education: A Plan of Action for the 80's." which outlined actions aimed at improving or restoring excellence in seven broad areas which affect directly the quality of engineering education.

To obtain advice on this proposal from major employers of engineers, the Society convened a meeting on December 14, 1983, of representatives of industrial member companies of ASEE and of other interested employers plus the QEEP Advisory Committee and several officers of ASEE. At this meeting, feedback was received from the attendees on the appropriateness of each area of the proposal to the quality aim and its relative priority among the tasks proposed. There was also discussion of the overall objectives of QEEP and of the rationale for concern about the present and future quality of the engineering education system.

Two primary points of consensus emerged from the meeting. The first was that the major issue is not one of the quality of BS graduates now entering the engineering workforce but rather whether the system of engineering education will be able to maintain that quality (and hopefully improve on it to take advantage of the superior qualifications of students now being admitted to the study of engineering) in view of the serious problems it now faces. There was agreement then by most participants that a focus on the quality of engineering education by ASEE is appropriate. The second point of general agreement was that the effort proposed in the draft document was too ambitious and that the focus should be sharpened to include a smaller number of higher priority objectives grouped around a central theme. From the comments of attendees both in the general sessions and in smaller discussion groups, there was evident consensus that the issue of maintaining a highly qualified faculty in adequate numbers is central to excellence in engineering education. The thought was expressed repeatedly that many elements which bear on quality (e.g., funding, admission standards, facilities, degree requirements, curricular options, etc.) are subject to short-term change given enough incentive and support, but a tenured faculty member is a major contributor to the quality (or lack thereof) of a program over his or her working lifetime.

With this as background, the QEEP Advisory Committee proposed a two-year program aimed at (1) insuring that U.S. engineering education has the faculty required for excellence in the decades ahead, and (2) addressing two critical issues in the future working environment of the faculty, the use of educational technology and the role of the undergraduate engineering laboratory. The project was formally launched on September 1, 1984, with support from 25 corporations. Four task forces of 8-10 persons each were organized with membership drawn from industry and academia. These are the Task Force on Preparation for Teaching of Engineering, the Task Force on Continuing Professional Development of the Faculty, the Task Force on the Use of Educational Technology and the Task Force on the Undergraduate Engineering Laboratory. The project has an Advisory Board composed of one member from each sponsoring company plus seven academic members appointed by the ASEE President. The project director for QEEP is the Executive Director of ASEE.

CHARGES

Task Force on the Preparation for the Teaching of Engineering:

> "To examine the current modes of preparation of engineers for faculty positions, to determine the adequacy of that preparation for the present and future needs of the profession, and to recommend changes if needed."

Task Force on Continuing Professional Development of the Faculty:

> "To study the present system of faculty development in the engineering colleges of the nation and to recommend ways in which the colleges can develop a systematic approach to insuring technical and pedagogical currency of each faculty member throughout his/her career."

Task Force on the Use of Educational Technology:

> "To identify the technology now available for potential use in improving the efficiency and currency of engineering education, to study the problems and promise of the variety of experiments underway in engineering colleges in the use of such technology, and to recommend a viable approach toward integration of appropriate technology into the engineering education process of the nation over the next decade."

Task Force on the Undergraduate Instructional Laboratory:

> "To study the current role of laboratory instruction in engineering education, to assess its future role, and to develop recommendations on means for insuring the full partnership of laboratory instruction in the engineering education process."

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7/17/85

Progress Report

ASEE Quality of Engineering Education Project (QEEP)

for the Period

September 1, 1984 - May 20, 1985

During the approximately nine months since the inauguration of QEEP, four task forces of 8-10 people each have been assembled to address the four areas on which the project is focused. These groups have held a total of eleven day-long meetings and have produced about thirty background papers dealing with issues contained in the charge of each. The chairmen made a progress report to the QEEP Advisory Board on February 7 and will do so again on June 18 during the ASEE Annual Conference in Atlanta.

Each task force plans to have its final report in draft form early this fall so that its preliminary conclusions and recommendations can be shared with several audiences for feedback prior to the preparation of the overall QEEP report by September 1, 1986. The reports will be circulated to the Board for comment, and presentations of these preliminary results are scheduled for five ASEE section meetings during the fall of 1985, for the ABET annual meeting, for the ASEE Fall Planning and Leadership Conference and for a plenary session at the College-Industry Education Conference in February, 1986.

On the following pages are summaries of the work of the task forces since their first meetings which were held between November, 1984, and January, 1985. The chairmen and other members of each group and the project director invite your comments, suggestions and criticisms.

Task Force on
Preparation for the Teaching of Engineering

John D. Kemper, Chairman

The Task Force has held two one-day meetings in Washington on November 13, 1984, and May 6, 1985, and one in San Diego, following the College-Industry Education Conference, on February 9, 1985.

Following the second meeting, research and writing assignments on major issues to be addressed by the Task Force were given to the members for presentation at the following meeting. These issues are (1) The Role of Research, (2) University/Industry Interaction: Adjunct Faculty, (3) Differing Needs of Engineering and Engineering Technology, (4) Teaching — Balance With Research and Other Faculty Responsibilities, (5) Effective Teaching Institutes, (6) Importance of Industrial Experience, (7) Graduate Education — Graduate Teaching Assistants, (8) Qualities Sought by Industry in Engineering Graduates and (9) The Role of the PhD in Engineering Faculty Preparation.

The Task Force originally had planned to produce a questionnaire for engineering deans and department chairmen and for industry to get perceptions about the adequacy of the current system of preparation for a teaching position. This approach was abandoned after discussion of the difficulty of designing an appropriate questionnaire and after agreement that most of the answers desired could be found either in the Task Force membership or through individual contacts with selected individuals.

The present schedule calls for a draft report to be prepared by the chairman, based on material which has been written by the members, for circulation to each member for comment in June. The draft report will be further refined at a meeting scheduled for August 20 and will be presented for discussion at the October 28-29 ASEE Fall Planning and Leadership Conference.

Task Force on Continuing Professional Development of the Faculty

Robert M. Anderson, Chairman

In its three one-day meetings the Task Force has (1) defined the goal of this study, (2) identified the issues which must be addressed in attaining the goal, (3) assigned each issue to one or more members for written commentary and discussion at subsequent meetings and (4) developed an outline for its final report. The outline is available to the QEEP Advisory Board. The chairman has prepared a complete draft of the report and has distributed it for comment to the members of the Task Force.

The Task Force has set as its goal to define and describe a comprehensive and actionable framework for engineering faculty development in a report which will be the definitive statement on the topic for the next 10-15 years.

The critical issue in faculty development has been defined by the group as insuring that engineering and engineering technology faculty maintain or achieve competence in: (a) current and emerging technologies and underlying sciences (in his/her specialty, outside the specialty, in a new specialty), (b) advancing the state of the art of the engineering education process. Continuing development of engineering faculty is felt to be particularly critical since, in contrast to the situation found in many other disciplines, the engineering knowledge base is continually changing.

The Task Force expects in its recommendations to provide a variety of options for viable faculty development programs to accommodate the diversity of size and type of engineering and engineering technology programs. The recommendations will suggest specific actions for specific groups (faculty, university administrators, employers, government, ABET, etc.). The draft report will be circulated widely for review and comment with the distribution list including members of the Advisory Board, engineering deans and a substantial number of faculty.

Task Force on Use of Educational Technology

Russel C. Jones, Chairmain

This task force is addressing its charge through the following agenda:

(1) Identification of the needs and problem areas in engineering education which can potentially be addressed through the use of educational technology

(2) Identification of the currently available technologies and of the programs applying them

(3) Assessment of the impact to date of the use of advanced technologies in engineering education

(4) Recommendations on future directions for use of technology in engineering education.

The three day-long meetings of the task force have been devoted primarily to discussion and refinement of written assignments in each of these areas, to reports on current experiments with use of technology and to descriptions and demonstrations of some commercially available systems (PLATO, IVIS). The Task Force plans to have a draft report written by September, 1985, and each member of the group will be writing a portion of the draft for review by August 15. The plan is then to present the preliminary findings and recommendations at a variety of meetings in the fall of 1985 and spring of 1986 to get as much feedback as possible before the final report is written. Also being developed for use in these presentations is a video/slide production which will illustrate existing uses of technology in engineering education.

The next meeting of the group is scheduled for September 5 at the IBM Education Center in Westchester, N.Y.

Task Force on the Undergraduate Engineering Laboratory

Edward W. Ernst, Chairman

The Task Force has held two one-day meetings and has a third scheduled for July 8.

An early conclusion of the group was that it should seek answers to the question of why laboratory instruction should be included in engineering education, what are we (or what should we be) trying to accomplish? In an attempt to answer this basic question, the members developed questionnaires which have been sent to three groups: (1) the industrial sponsors of the Quality of Engineering Education Project, (2) the professional societies which are members of ABET and (3) a selected group of educational institutions. Each group has been asked to respond to three separate questionnaires dealing with laboratory instruction for engineering students, four-year bachelor of engineering technology students and students in two-year associate degree programs in technology. Three sub-committees of the Task Force will analyze the responses and report to the entire group at its July 8 meeting.

A draft outline of the final report has been prepared indicating the areas to be addressed in the report. There is consensus in the group that there will probably not be sufficient money available nationally on a sustaining basis to solve one major problem confronting engineering undergraduate laboratories, that of keeping equipment near state-of-the-art in the face of rapid changes in technology. The Task Force therefore hopes to recommend some new approaches to laboratory instruction, including several viable options to accommodate the variety of educational institutions. The report will also deal with the current barriers to development of excellence in laboratory programs and with steps required for removal of the barriers.

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APPENDIX 5

SUPPORT FOR GRADUATE EDUCATION IN BIOMEDICAL AND BEHAVIORAL RESEARCH

COUNCIL OF ACADEMIC SOCIETIES

SPRING MEETING 1985

aamc association of american medical colleges

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Research Training and Research Resources Officer
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Research Training in the Biomedical Sciences: an Overview of Strengths and Vulnerabilities

Nowhere is the complexity of biologic systems and the sophistication needed to perform research in the biomedical sciences as clearly demonstrated as in the program required to prepare a young aspirant to become a creative and contributing investigator in the biomedical or biobehavioral sciences. Such research training now requires at least a decade of advanced study after receipt of the baccalaureate degree. For the Ph.D. the average is 7.5 years to obtain the doctoral degree and three years of postdoctoral training. For the M.D. who seeks a research career, a base of four years of medical school and at least three years of residency training is necessary before embarking on actual research training, which, undertaken in coordination with advanced subspecialty training, can easily take at least three years. This enormous personal commitment on the part of the aspiring scientist, with no guarantee that he will ultimately prove capable of self-sustained research creativity, must be matched by an intensive commitment of the personnel and laboratory resources necessary to accomplish this highly individualized training process. One somehow has a sense that the scale of this effort is as great as its intensity.

Yet, in actuality, reasonably reliable estimates drawn from multiple sources by the speakers in this symposium indicate that if one seeks fully trained, independent investigators, this nation is producing perhaps 2200 such fully-trained Ph.D.s, 1200 research M.D.s and 150 M.D./Ph.D.s per year. Some

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smaller number of people may receive a portion of this training and thereafter contribute, in varying capacities, to biomedical research.

Not only are the devoted individual attentions of research mentors and the full facilities of top flight academic research laboratories and clinics necessary to train this critical cadre of future investigators, but a wide array of funding sources must be tapped to obtain funding for the stipends of these graduate and postdoctoral students, the tuition of the degree candidates, and, where possible, some modicum of support for the research training sites themselves The degree to which these years of training are an apprenticeship in which the trainee learns while participating actively in the laboratory or clinical work, is reflected in the sources of funding. In the major university training programs, research project funds support 30 percent of bioscience Ph.D. candidates and 42 percent of postdoctorals; patient care revenues support perhaps 65 percent of advanced subspecialty M.D training. These funding sources both tie the trainees to duties which may or may not contribute optimally to their research training and make the national training effort vulnerable to unrelated funding perturbations such as those which occur in the individual grant renewal process or when proposals are made to preclude the use of Medicare hospital funds to support subspecialty training.

That portion of the diverse resources supporting the education of future biomedical investigators which is specifically designated for training in research thus plays a crucial role in the entire support system. Federal support represents a significant portion of all funds specifically dedicated to doctoral and postdoctoral training in the biologic sciences, ranging in 1983 from 12 to 15 percent of support for Ph.D.s trainees to 34 percent of Ph.D. postdoctoral support, and 45 percent of support for M.D. postdoctoral research training. Other sources of support such as teaching assistantships for Ph.D.

candidates, or private foundation or industrial programs for some postdoctorals provide a range of support mechanisms which assure a desirable heterogeneity and flexibility in the system.

What are the particular vulnerabilities of this current system of research training in the basic and clinical biomedical sciences? A number are identified by speakers in this symposium. First, and most potentially worrisome is the decline in the number of young people receiving a baccalaureate degree in biosciences from 5.5 percent to 4.1 percent of all college degrees awarded. A predictable result of this trend is the 9 percent decline in medical school applicants in 1985.

A further vulnerability is the clear dependence on federal resources to sustain the current scale of graduate training programs; a scale which has in large measure contributed to our international leadership in the biological and biomedical sciences. Over half of all training resources at our major graduate school sites are federal, either through direct training support or research grants which incidentally employ trainees. Should the federal resolve to make this investment in the advance of biologic knowledge and health research weaken, no other source could assume this burden.

Within the overall federal investment, there should be concern that research grants not become the dominant source of funds. Their merits and weaknesses are well rehearsed by our speakers; they are an important resource but not always congruent with optimal educational experiences. The NAS Committee on Personnel Needs in Biomedical and Behavioral Research has always strongly recommended that the major federal investment should be directly in institutional training grants.

These crucial federal training grants and fellowships have another potential vulnerability; with the exception of a few NSF programs, the major federal training effort in the biomedical sciences is based in a single law, the National Research Service Awards Act, first enacted in 1974 when an administration doubting the wisdom of federal investment in biomedical research training stripped the NIH of the authority it had had since its inception to make grants for research and research training. This vulnerability to a single law has been amply demonstrated by repeated battles over its reauthorization and resulting limitations of training appropriations. Onerous as well is the provision in this law that a trainee must pay back in future work or return of funds the training stipend awarded him by merit and earned as well by contributing to the national research effort during training. This payback provision is widely held to discourage some fraction of our bright young people from essaying the perils and pleasures of a research career.

One of the touted strengths of the American scientific system is that research training and cutting edge scientific research proceed hand-in-hand in our premier academic institutions. The synergy made possible by this confluence of learning, doing, and teaching is universally believed to contribute to our preeminence. Some 90 percent of our biomedical scientists are trained in the top 100 of these research institutions and their medical schools. Does this concentration of training to a cadre of our universities introduce a vulnerability? Perhaps, but the prolonged, personalized, highly sophisticated education we are discussing is best accomplished where the best research is being done, where the best mentors and facilities are, and where the enormous resources, often extending to access to major medical school teaching hospitals, are concentrated. It is a measure of the wealth of this nation that there are at least 100 such centers of excellence and perhaps unwise that the present limited resources or the trainees be dispersed more thinly.

Two areas in which we must continue and expand our efforts in training are in insuring an adequate supply of scientists such as geneticists or immunologists, with the disciplinary skills necessary to capitalize on the recent advances in molecular biology, and in training a large enough cadre of M.D. investigators to insure a fruitful link between basic biological research and improvement of human health. Specially tailored support mechanisms and greater investment in current mechanisms may be necessary to produce greater numbers of Ph.D. investigators who combine generic training in the classic disciplines and interdisciplinary training, with specific methodologic training in these new areas. Such generic and broad based training is critical to enable these young people to remain at the forefront of rapidly advancing and changing research frontiers. M.D. scientists represent, as they have for some years now, a valued but endangered resource. The long years of arduous clinical and research training, the debt burdens of many graduating M.D.s, their difficulty in competing with full time research Ph.D.s for limited research grant funding, and the increasing pressures to contribute to sustaining the patient base of their medical centers combine to discourage many capable people from careers in clinical research. Special programs to assist in recruitment and retention of M.D. scientists are critically needed. A number of NIH initiatives are reviewed in this symposium; their combined effort may have stemmed the sharp decline in M.D. trainees apparent in the late 1970s, but the problems of the low numbers of M.D. trainees and their ability to sustain research careers have not yet been reversed.

AAMC
July 1985

Elizabeth M. Short, M.D.
Director
Division of Biomedical Research

Symposium Participants

The Council of Academic Societies of the Association of American Medical Colleges held its 1985 Spring meeting on March 14 and 15 in Washington, D.C. The plenary session, Support for Graduate Education in the Biomedical/Biobehavioral Sciences, was designed to address both current public policy concerns about financing graduate education in the biomedical/biobehavioral sciences and the changing educational environment for M.D.s and Ph.D.s. The four speakers were chosen because of their considerable background and expertise with these issues.

Robert M. Bock, Ph.D. is Professor of Biochemistry and Molecular Biology and Dean of the Graduate School at the University of Wisconsin, Madison. He is the chairman of the Basic Biomedical Sciences Panel of the Institute of Medicine Committee on National Needs for Biomedical and Behavioral Research Personnel and a member of the National Academy of Sciences (NAS) committee to evaluate the quality of the research doctorate. His national contributions have included chairing a NAS committee on the vitality of academic research, which published a report entitled, "Research Excellence to the Year 2000", and reviewing the Science and Technology Education Plan of South Korea for the World Bank. He currently serves on a NAS committee to evaluate scholarly exchange with the People's Republic of China.

Frank G. Standaert, M.D. is Professor and Chairman of Pharmacology at Georgetown University Hospital. He is a member of the Basic Biomedical Sciences Panel of the Institute of Medicine Committee on National Needs for Biomedical and Behavioral Research Personnel. He currently serves on the National Research Council Committee on Recommendations for U.S. Army Basic Scientific Research, the NIH Biotechnology Resources Review Committee and the National Board of Medical Examiners Pharmacology Committee.

Harold J. Fallon, M.D. is Professor of Medicine and Chairman of the Department of Medicine at Virginia Commonwealth University, Medical College of Virginia. He is chairman of the Internal Medicine Residency Review Committee and a member of the American Board of Internal Medicine. He serves on numerous editorial boards, councils and committees, including the Council of the Association of Program Directors of Internal Medicine and the Advisory Council for the National Institute of Arthritis, Diabetes, Digestive and Kidney Diseases.

Doris H. Merritt, M.D. is Research Training and Research Resources Officer at the National Institutes of Health and Special Assistant to the Director NIH. Before returning to NIH full-time in 1978, she was Professor of Pediatrics and Dean for Research and Sponsored Programs at Indiana-Purdue University in Indianapolis. At NIH she has multiple responsibilities but is particularly knowledgeable about the overall NIH effort in research training through the National Research Service Award program and the Career Development awards.

Support for Graduate Doctoral Education: Predoctoral Ph.D. Education

Robert M. Bock, Ph.D.

As background information to a discussion of the different mechanisms of support for predoctoral Ph.D. education, I will first describe the general characteristics of the current Ph.D. output. The graduation rate for Ph.D.s in all areas of science and engineering is approximately 18,000 per year, which is three times the number in 1960. Of these, approximately 4,800 per year receive degrees in the biological and agricultural sciences. However, when these graduates are viewed as a percentage of their age cohort, this growth rate is not as impressive as it first appears. In 1960, 0.15 percent of the U.S. age cohort achieved a Ph.D.; in 1983 it was 0.3 percent. The growth can be attributed almost entirely to two groups: the increased participation of women in Ph.D. training and the increased proportion of foreign nationals graduating from American universities. The percentage of American males graduating has actually decreased in the last 15 years. We have undergone a shift, much of which was needed in order to extend equal opportunity to underrepresented groups. We were not creating optimum opportunities for scientific and engineering personnel when women were excluded because of habit, tradition, or perception. In the life sciences the percentage of female Ph.D. recipients has risen to 27 percent, accounting for almost all of the increase in graduates within the last decade. (Figure 1)

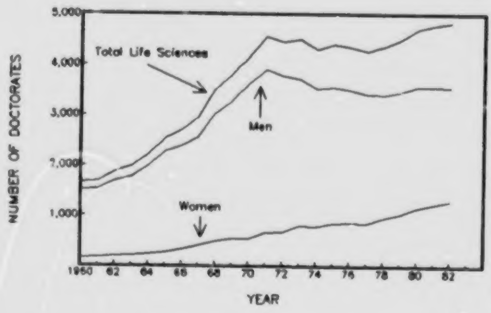

Figure 1: Life science doctorates granted to women increased each year while the number of new male Ph.D.s have remained relatively constant.

Source: National Science Foundation and National Research Council, Science and Engineering Doctorates 1960 – 1982; NSF Publication #83-328

Maintenance of sufficient numbers of new doctorates is dependent on the high school graduates entering scientific curricula in our universities. These young science majors provide the college graduate pool from which our biomedical researchers are selected for Ph.D. training. In the 1980s, approximately 50 percent of all children born will be in ethnic minority groups which are currently underrepresented in the Ph.D. researcher population and in the science bachelors pool from which these researchers are selected. Unless our society provides educational opportunities adequate to prepare this new generation to pursue advanced scientific training, the nation will face in the year 2000 biomedical and scientific research needs greater than can be served by the pool of adequately prepared young people.

Another notable characteristic of the Ph.D. output is the wide variation in the numbers of graduates among fields. The bioscience field with the largest percentage growth at the current time is immunology, followed closely by the neurosciences, and for the last decade, molecular biology. These three disciplines have all had real growth in Ph.D. output. Many other areas are stable and a few have declined; e.g. biophysics has actually declined in Ph.D. output over the last decade. It is interesting to note that the output from all of the life sciences Ph.D. programs combined only equals the Ph.D.s awarded yearly in psychology and the behavioral sciences. Without a doubt, the largest single field is psychology. In fact, the next four or five fields combined barely equal the number of psychology Ph.D.s graduated each year.

Any discussion of support for Ph.D. education must recognize not only the variations in size between fields, but also the tremendous diversity in support patterns between fields. For example, in psychology, support from research grants and training grants is quite modest compared to that from teaching assistantships. This paper will specifically examine the support mechanisms that are utilized in the biomedical and life sciences.

The competition for the principal sources of support varies widely by institution as well as by field. The distribution of Ph.D.s awarded is uneven among the schools, with two-thirds being awarded by the top 50 Ph.D. producing schools and 90 percent by the top 100 schools. This paper will be descriptive of the characteristics of these top 50 schools, rather than trying to encompass the entire Ph.D. producing universe.

Current enrollment in graduate science and technology programs is on the order of 400,000 persons of whom one-third are in programs leading to the Ph.D. The principal categories of research support for these Ph.D. candidates are the research assistantship, the teaching assistantship, and the NIH research traineeship. According to my analysis, research assistantships provide the largest single fraction of support in the life sciences, with about 30 percent of all students supported as research assistants. The NIH is the primary source of funds for research assistantships and the National Science Foundation is second. A substantial number of graduate students are now being supported on grants from industry, primarily the pharmaceutical, and more recently, the biotechnology-related companies. Other sources of research support include philanthropic foundations, state and university endowment-based fellowships or research assistantships, and a variety of miscellaneous sources (see Table 1).

Table 1

SUPPORT FOR PREDOCTORAL PH.D. EDUCATION IN THE BIOMEDICAL SCIENCES

Support Mechanism	Approximate % of Total Support
Research Assistantship	30 %
Teaching Assistantship	20–35
Research Traineeship	15
National Science Foundation fellowship	<5
Loan programs	5
Philanthropic institution–based fellowships	3
Other	
Federal programs in targeted need areas	
Work–study programs	
Industry–institution relationships	

Percentage support is based on information from the top 50 Ph.D. producing schools which produce two–thirds of the new doctorates. There is wide diversity between public and private institutions and between departments.

What are the advantages of a research assistantship? From the university's perspective, research assistantships are a stable and beneficial source for funding a high quality graduate program. Quality is maintained through the peer review process, with funds awarded to the principal investigators who write the best proposals, who have the best track records, and who are therefore excellent models for the current and coming generations of researchers. The principal investigator decides the best strategy to expend the research dollars to achieve a recognized output, such as publications in peer reviewed journals, that will help ensure the success of future grant applications. Stipend policies are established at the institutional level so there can be local decisions concerning the cost of living in the area, rather than an average of all institutional competitors. Policies for tuition and indirect costs are negotiated between the federal government and the institution, but in general they are covered in a manner that is acceptable to both the auditors and the institution. Indirect costs are calculated on a base that includes the stipends of research assistants; thus their presence contributes to maintenance of the overall research environment.

For the research assistant there is another advantage to this type of support. In most university appointment structures, a research assistantship will automatically qualify the graduate student for the institutional health insurance policy. This is a very valuable benefit because of the cost of health care and the substantial fraction of Ph.D. candidates who are married.

There is one disadvantage for the research assistant; instability of the funding. The large volume of research assistantships makes this a stable source of support from the overall perspective of the university, but when you look at the microcosm of one research group or one student, it is unstable. This year, for example, there is great uncertainty for those students relying on a research grant renewal from NIH because of the mid-year change in the number of grants OMB will permit NIH to support. Both NIH and NSF, the two principal supporters of biomedical research, are concerned about grant stability and are considering increasing the length of the research grant. An increase from two or three years to five years would greatly improve stability of planning for the principal investigator and for the graduate student who is entering into a serious in-depth research problem.

In the top 50 research institutions the teaching assistantship is the second principal source of support for graduate students. Teaching assistantships range from 20 to 35 percent of the support for graduate students, depending on the type of school. The availability of and need for teaching assistants (TAs) is tremendously diverse even within one institution and differs dramatically between public and private institutions. State institutions, in general, expend almost twice as large a fraction of their instructional support through teaching assistantships as do private institutions; consequently, more TAs are supported in state institutions than in private institutions. Between departments the diversity is even greater. In colleges of arts and sciences, the fraction of Ph.D. candidate students supported as teaching assistants may be three times as great as in the basic sciences in a medical school. This is because of the increased need for TAs to teach large undergraduate sections of chemistry, math, physics, biology, zoology and botany, compared to some of the new areas of the medical sciences, which focus on a narrow subfield such as neuroscience or immunology, and have less need for large numbers of TAs. One should also recognize the wide diversity that exists in the work demands of different teaching assistantships, especially for the TAs instructing large undergraduate classes.

What are the advantages and disadvantages of the teaching assistantship as a source of support for graduate education of Ph.D.s? Certainly it is an important part of training faculty for the future and helps the institution keep its vitality. Teaching assistants are often very good instructors who relate well to the students, who are only a few years younger. But there are some disadvantages. It is a time consuming activity. Teaching assignments can be very disruptive if they coincide with deadlines on a research project or grant application. Such a student might be a negative asset to the research unit because he or she is occupying lab space, but is not using it fully while teaching the undergraduate laboratory. For students there is the financial disadvantage that a teaching assistant appointment is taxable, which results in a higher cost to the student. Some institutions avoid the tax problem by requiring a teaching experience of every degree candidate, in which case the appointment can be defended as a teaching fellowship and is non-taxable.

Now we come to one of the most beloved, defended, and argued about sources for graduate support and that is the federal research traineeship. The National Institutes of Health have been the inventor and promulgator of a longstanding and very successful research training program. The magnitude and percentage of support provided through the training grant mechanism has varied dramatically over the years. At one time not only were the numbers of predoctoral students supported by NIH twice as large a percentage of the predoctoral Ph.D. cohort as they are today, but the training grant was sufficiently well funded that it had a tremendous impact on the quality of the entire graduate program. The non-stipend portion of the grant enriched the entire training milieu, providing the opportunity for guest lecturers, for books and for travel to scientific meetings by the trainees.

In 1974 the National Research Service Awards Act was passed by Congress to markedly restructure, affirm, defend, and codify the commitment of NIH to training the researchers of the future. In the last decade, pressure on the available funds has led to a shift of almost all the training monies into direct costs such as tuition and trainee stipends in order to try to support the same number of trainees on diminishing dollars. This pressure to preserve the number of trainees has necessitated very dramatic cuts in the allowable "indirect" or institutional support for the training program. Today with a maximum of 8 percent administrative costs, that support averages about 30 percent of the amount per trainee that it did at the peak. However, it is still a very important supplement, enriching the training environment in the departments and schools that are fortunate enough to have a training grant.

About 15 percent of life science/behavioral science Ph.D. candidates are now supported by the NIH predoctoral training grant program. What are some of the advantages of this category of support? The great advantage is that these grants are typically five-year institutional grants with a good probability of renewal if performance is high. Because of this stable support and because these grants are specifically addressed to the research training mission, the training setting can be carefully planned. The NIH predoctoral training grant provides for a more careful balance of training activities than is possible with an individual research assistantship, thus assuring that the student is well trained in the central discipline of the training grant as well as the specific methodology of his research group. Analyses of productivity of graduates of this research training program are very gratifying. Students who have had the benefit of training grant support outperform those trained by any other broad category of support mechanism as judged by output of peer reviewed publications per individual, scores on competitive research grants, and the probability of staying in biomedical research. Because this program outperforms any other sources of support by a modest but significant increment, it is a very valued program for research training.

In general the training grant has a substantial cost/benefit for the institution. It is efficient and well run, with trainees progressing through the program in a timely manner. However, the stipend levels are under control of the NIH and have lagged behind the stipends that are common for research assistants and fellows funded by other agencies. While this means an economy for the supporting agency, for most institutions non-federal funds must be found to supplement the grant or other institutional mechanisms must be used to keep the trainee from being disadvantaged compared to other research assistants funded by NSF or other sources.

Another problem currently facing the training grants and their administration is tuition costs, which have recently become a larger and more visible percentage of grant costs. Both stipends and the enrichment program have been held down or cut back in recent years, but tuition has been paid at the level set by the institution. While it is true that tuition is tied to some given percentage of the instructional costs, it has risen at or above the national cost of living index, and has become an ever larger fraction of the training grant budget. In order to limit its tuition commitment, NIH is currently proposing that the actual institutional tuition in the initial grant year be taken as the base, and that out year tuition support be limited to a maximum of 6 percent annual increments above the base. If inflation is controlled, I think tuition increases can stay within that 6 percent increment. However, if institutions experience substantial inflationary costs, then tuition increases will exceed this new ceiling and NIH training grants will no longer cover the actual share of institutional costs for which tuition is intended.

A disadvantage of the NIH training grant for the trainee is the payback requirement. The payback clause in the NRSA legislation is seen by an entering student as a potential problem. Each research trainee must sign a commitment to return the money that supported their education if they opt to choose a career outside of research. The payback provision is much more of a threat than a reality; in fact, very little money has been paid back to date. Perhaps its very existence makes students vote with their feet if they have any question about their career choice. The payback provision was enacted to counter accusations that federal training support was being used to enhance the skills of future high income professionals rather than to increase the number of research scientists. The provision has the political advantage that it is currently possible to certify that these monies will not be wasted on non-researchers because they will be paid back to the taxpayers if the trainee does not become a researcher. There are studies underway to examine the impact of the payback requirement on research career recruitment and the need to continue this requirement. It may change in the future, but politically the payback clause was the savior of the stable training grant program at the time of its enactment in 1974.

The NIH research training grants also support the only national program for combined M.D./Ph.D. candidates, a program which currently enrolls just under 700 medical scientist trainees. Such candidates participate in a planned and coordinated graduate training program, enabling them to attain both the M.D. and the Ph.D. degrees. This Medical Scientist Training Program (MSTP) has had a very high priority from the National Research Council and has been strongly supported by the Institute of Medicine Committee that reviews the National Research Service Act and recommends to Congress what the federal role should be in research training in the medical sciences. These physician-investigators are building a very important bridge between basic science and clinical applications for the solution of health problems and provide both the interface and the conduit for new information into health care.

The number of MSTP trainees is modest and the quality of the applicants who cannot be accommodated is high, so that if resources were available the program could fruitfully be expanded. While the present national investment in 700 trainees should clearly be sustained, the National Advisory Committee has recommended every year that a greater number of M.D/Ph.D.s should be trained. However, there are problems in implementing this recommendation. Because of the greater length of the M.D./Ph.D. program compared to the Ph.D. only, the costs per graduate are substantially higher. In addition, medical school tuition costs are generally higher than graduate school tuition costs. The projection for 1986 is that it will cost $15,000 per year per predoctoral Ph.D. trainee, combining stipend, tuition, and ancillary allowable training costs. However, for the MSTP trainee the costs will be $19,000 per year per trainee. Furthermore, the medical scientist trainee is permitted to participate for up to six years in this program. Some training time may be spent as a research assistant or as a fellow, so not all MSTP trainees use the maximum six years, but most do. For the predoctoral Ph.D. training program, there is a maximum of three years support per trainee, with permission to extend support in extenuating circumstances. The average appointment to the Ph.D. training grant is only two years. The result is that the cost per graduate is more than twice as great for the M.D./Ph.D. as for the Ph.D. training track. In addition to this substantial commitment of NIH training funds, the MSTP program requires an institutional commitment of time, attention, and devotion to the concept. The institution must find the research training opportunities and coordinate the trainees as well as provide flexibility in the M.D. program to permit these students to maximize the research portion of their training. Nevertheless, the physician-scientist plays such an important role in medical research that the program should be defended in those training sites which are well managed and produce outstanding products.

Predoctoral Ph.D. education also is supported by other mechanisms. National Science Foundation fellowships are a very valuable mechanism of support and are used quite extensively in the biomedical sciences. These fellowships have certain distinct advantages: they go to top students, they support a three-year program, and they have a high stipend (currently $10,000 per year). They also are "portable" which is both an advantage and a disadvantage. NSF fellows flow to the most attractive institutions in a particular field. That makes the strong stronger, as the NSF fellows go to the schools with the best reputations. The disadvantage is that because only a few schools in a limited number of states have highly competitive programs, NSF fellows are not evenly distributed. Those universities without such programs lobby against the "portable fellowship" concept. However, I think that because the fraction of the graduate student population supported as NSF fellows is less than 5 percent, it is not a misuse of federal funds to recognize quality and let these top caliber students go where they think they can get the best training. Another disadvantage of the NSF fellowship is that tuition costs and the indirect costs of supporting the training program must come entirely out of the institutional allotment. In many state institutions and almost all private institutions the institutional allotment is less than the tuition alone. As a result, institutions have to decide whether to accept these good students who have three years of stipend support, without a mechanism to collect full tuition from their grants. Accepting NSF fellows is a major cost to schools such as Harvard, Stanford, Johns Hopkins, and MIT, where many NSF fellows want to go and where the tuition rate may be double the institutional allotment.

A number of other federal agencies have modest fellowship activities. The U.S. Department of Agriculture has recently begun a fellowship program in targeted areas of national need. The Office of Education has the Graduate Professional Opportunities Program (GPOP), which is modest in size and is intended to provide high quality Ph.D. training to minority students. There also are programs within NSF and NIH that address the particular problems of initiating access to research experiences for minority students so that they will have a chance to move into the mainstream of biomedical research. In addition, these programs provide an important component of the overall research support.

Institutions also look to the alumni, to their friends, and to philanthropic foundations for student support, primarily through the fellowship mechanism. This is an important source of support, which varies greatly by institution. Nationally, only about 3 percent of the graduate student support comes through institution-based fellowships, but in some schools it may be much greater than that.

There has been some substantial growth in the interest of industry in insuring that high quality students continue to be trained, especially in the new areas of science that they see as future needs. Where these relationships are established between specific companies and schools, e.g., Monsanto with universities in St. Louis and Boston, they do bring quite substantial graduate student support for the institutions. They are not a general solution, because such arrangements are difficult to negotiate and are not widely available but they do have a significant role and have grown over the last few years.

There are other large student support activities that have only a modest impact on Ph.D. training in the biomedical sciences. One example is the work-study program. The dollars paid per year nationally in work-study support dwarf the combined NSF and NIH training activities; however, their impact on Ph.D..training is very modest. Bureaucratic requirements have been erected that make it difficult for the graduate student to benefit at a level that is comparable to current stipend levels for research assistantships and NSF fellows. A few universities have established work study programs for Ph.D. candidates, but they are the exception not the rule. Northwestern University has done this quite successfully, but financial aid officers at most universities direct work-study support to undergraduates as the first target.

What about loan programs? We are all aware of the enormous public policy debate about the cost and magnitude of loan programs for education. The principal loan program impact on Ph.D. candidates in the sciences is the debt incurred as undergraduates. About 10 percent to 12 percent of students come into graduate school with a substantial loan burden, which is deferred until they have finished their Ph.D. program. The fraction of biomedical research graduate students who participate in further loan programs is well under 10 percent. In a typical institution perhaps 5 percent of Ph.D. candidates have to continue to obtain loan support. Usually these are cases where there are unusual family costs, forcing the student to supplement the support available to research assistants, teaching assistants, or trainees. Although the loan programs are a fundamental building block of undergraduate educational opportunity and of professional school opportunity in medical, veterinary, or law school, they are not one of the major support programs in Ph.D. training.

In conclusion I would like to reiterate the major sources of support for predoctoral Ph.D. education in the biomedical and life sciences. The primary source of funding is the research assistantship, which provides support for approximately 30 percent of life science students. The teaching assistantship is nearly as important, supporting 20 to 35 percent of students, depending on the type of school and the specific field. The NIH predoctoral research traineeships support 15 percent of life science/behavioral science Ph.D. candidates, as well as a small cadre of M.D./Ph.D. students. The results of this federal training investment have been excellent and amply justify continued federal investment in this successful program. Other support mechanisms include the National Science Foundation fellowships for 5 percent of students, targeted federal fellowship programs for areas of national need or to encourage minority students, institution-based fellowships, and industry support of graduate students in specific new areas of science. Two large student support mechanisms that are used extensively by undergraduates and professional schools, but which are not a significant source of support for predoctoral science training for Ph.D.s are the work-study program and various loan programs. The choice of support mechanism is influenced by the structure and format of the training program. At the same time the specific field, the type of institution, and the reputation of the institution and its professors help to determine which type of training support will be utilized. Together, this mix of support mechanisms provides the variety and flexibility necessary for Ph.D. training in the biomedical sciences. The federal role in support of research training in the biomedical sciences is crucial, with one half of all support coming from federal training or research grants. This federal contribution must be sustained to continue our national preeminence in these fields.

Support for Graduate Doctoral Education: Postdoctoral Ph.D. Education

Frank G. Standaert, M.D.

The training of Ph.D. postdoctorals is the most amorphous part of the system that prepares people for research careers in the biologic sciences. Naturally, one cannot ignore the forces that shape the predoctoral programs because whatever affects the predoctoral program eventually will affect the postdoctoral program. It is important to note, however, that predoctoral candidates are almost always in a structured program within a university, and are bound by course and laboratory requirements. Once the degree is obtained, a Ph.D. is much less constrained, having available a wide choice of career opportunity and training both within and outside the university. The system for postdoctoral training, if indeed it is a system, is very broad, very individualized, and very difficult to summarize. For example, it is not possible to state how many postdoctorals there are in the United States. The reason for this is simple. We know who begins as a postdoctoral trainee because anyone who gets a doctorate degree automatically becomes a potential postdoctoral trainee. Unfortunately we do not know how many end the postdoctoral period because there is no time that clearly marks an ending. Without knowing how many exit the postdoctoral period, the size of the pool can only be estimated.

In the minds of many people, the postdoctoral period is a well-defined training position of fixed duration, from two to four years, following which the individual moves on to another job; i.e., it is a time when the scientist is in an apprenticeship and is preparing for an independent career in research. That is not really what happens. A substantial number of people stay in a quasi-postdoctoral position until they eventually stop calling themselves postdoctorals and use titles like research associate or senior technician. In a very real sense the end of the postdoctoral period occurs when an individual says so. There is no sharp dividing line between when an individual is in a postdoctoral position and when he is in a permanent career position. This discussion will include data sets that have been compiled from a variety of organizations including the National Research Council, NIH, ADAMHA, and the National Science Foundation. Unfortunately, these data sets are not exactly comparable because the definitions of the various categories change from one organization to the next. What is more important than the precise numbers are the trends that are occurring. These general trends are apparent even though the numbers may vary by 10 or 20 percent in different studies.

All of this unpredictable, uncategorizable postdoctoral activity is appropriate for individuals who are becoming independent investigators, because exactly how one achieves this independent status varies with each individual's desires and needs and with the available opportunities. Most observers consider this early postdoctoral period to be very important in shaping the professional life of the future scientist as well as the entire American research enterprise. For the individual the postdoctoral period provides more freedom than he or she probably ever had before or will ever have again. The postdoctoral trainee usually works on someone else's grant, so he has all the freedom of not having to write grant requests or progress reports. He has completed the student period so there are none of the student requirements that we impose on doctoral candidates. He is usually better off financially, though the system does not pay postdoctorals very well. Each is usually working for a well-known institution or person from whom he learns a lot and gains reputation by association. A postdoctoral trainee also has the all important commodity -- time. For once in his life he can immerse himself in science. He knows how to do it, and has the time and opportunity and someone else's money with which to do it. And finally, because the postdoctoral trainee has no reputation to defend, he can afford to take a chance. He can try ideas that more senior people would shy away from and has the freedom to do things he wants to do that may not work. So he has time, he has freedom, he has ample opportunity to train, and in fact it is a very good time in a young scientist's life.

In addition to the benefits for individuals themselves, the research system depends heavily on these people. Without postdoctorals the American research effort would be very different. Individuals in postdoctoral training are intelligent, well-trained, and highly motivated to do research. Furthermore, most of them are young, physically as well as intellectually vigorous and retain the curiosity and inquisitiveness of youth. They probe into areas that minds already set into molds do not even consider. The challenging work they undertake and their interaction with the faculty have an invigorating influence on the entire laboratory. They are ambitious, publish regularly, and attend meetings. Perhaps most importantly for the system, they leave their postdoctoral positions after only a few years, so turnover is rapid and an active laboratory can count on a constant stream of fresh young minds and new talents to pursue research vigorously and to publish it rapidly. It is a self-feeding system with the more renowned research groups attracting more postdoctoral trainees. The greater the number of postdoctorals, the more exciting the atmosphere and the greater the productivity of the laboratory. This aids the progress of the individual trainee and advances the whole research enterprise. In many ways, our modern American research system of research by interdisciplinary teams with multiple collaborators and authors is really based on the postdoctoral trainee. Without the constant influx of new intelligence, new techniques, and new ideas, much of the work that is going on would stagnate.

Who are the postdoctoral trainees? According to the statistics that are available, in 1983 there were about 5,500 life science Ph.D. graduates. The life sciences include biological, health, and agricultural scientists. Of these, about 80 percent were U.S. citizens and about 20 percent were citizens of another country at the time they received their degree. About one-third of the foreign students had permanent resident visas and the others had student visas. Of the U.S. citizens, about half planned to do postdoctoral training and about half to go directly into employment. This statistic is something of a surprise because many in academia automatically assume that almost all new Ph.D.s will take postdoctoral training. About 48 percent of those who seek employment will go into research and development, usually in industry, and about 28 percent will go into teaching, largely in undergraduate courses or specialized professional schools like pharmacy. Therefore, in examining post Ph.D. education, we are dealing with the specialized half of the pool of graduates that seeks this type of research training experience.

Table 1 illustrates the changes in post-graduation plans over time. In 1970, only 40 percent of graduates sought postdoctoral study; 32 percent had definite plans, and 8 percent were looking for a spot. By 1983, this had risen so that 60 percent of the graduates were planning to do postdoctoral study. More and more graduates in the biomedical sciences are moving into postdoctoral training and, conversely, there are fewer people seeking employment directly after receiving the Ph.D. degree. Of those seeking employment, fifteen years ago nearly two-thirds were looking at academic positions. Today only one-third will seek an academic job without postdoctoral training. The difference is that today academic departments expect postdoctoral work before they will offer a position. Because of this expectation, a larger percentage of graduates are looking for postdoctoral training and there are more postdoctoral training opportunities.

Table 1

PLANS OF PH.D. STUDENTS FOLLOWING GRADUATION 1970, 1975, 1980, 1983

Student Plans	1970	1975	1980	1983
Postdoctoral study				
seeking a position	8%	10%	12%	12%
definite plans	32	41	48	48
Employment				
seeking a position	12	12	10	12
definite plans in:	43	30	25	24
academe	31	18	14	13
industry	5	4	5	5
government	5	6	4	4

Source: National Research Council, Office of Scientific and Engineering Personnel, Doctorate Records File

Two very interesting trends in basic biosciences manpower are shown in Figure 1. After rising steadily for over a decade, the number of bioscience Ph.D.s awarded plateaued in 1972. Since then, the number of bioscience Ph.D.s awarded nationally has been essentially stable at 3,500 per year. The number of bioscience postdoctoral appointments shows a striking, continuous rise in the last decade, despite the fact that Ph.D. output has been unvarying. While one might expect a lag time of three to four years between the number of postdoctorals and the number of new Ph.D.s, Figure 1 indicates a much longer lag time. The data suggest that Ph.D.s who graduated some years ago are staying in postdoctoral positions longer or that more new graduates are finding postdoctoral work, or both. This observation that the postdoctoral pool is expanding has stimulated a concern that we have created a large pool of underemployed highly qualified scientists who should be able to leave the postdoctoral pool, but are unable to find a job because of economic stringencies. I think there are a number of other trends contributing to the increased number of postdoctorals. One is that we expect more postdoctoral training. In the 1940's, postdoctoral training was not required of a new faculty applicant. As science became more complex, the training expectations rose. Now one expects two to three years of postdoctoral training for faculty applicants as well as for scientists for a number of other positions. A second factor contributing to the increased number of postdoctorals is that some people never leave the postdoctoral pool. They stay on to function as supertechnicians, instrument specialists, and research managers, but are counted as holding postdoctoral positions until they change their job title. We have trained a fair number of people who are not really independent investigators, but who are essential to the team concept, large-scale research that we are doing today. Despite these forces contributing towards expansion of the postdoctoral pool, there is evidence that suggests this growth may be leveling off or even reversing. Figure 1 illustrates a slight decline in the number of postdoctorals beginning in 1982.

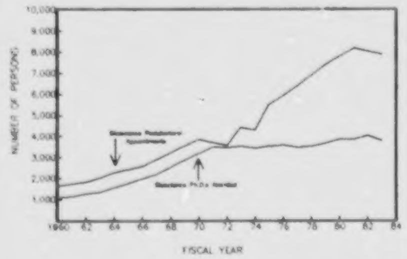

Figure 1: While the number of bioscience Ph.D.s awarded yearly has been stable since 1972, the size of the postdoctoral pool steadily increased until 1982

Source: Data from the 1983 Institute of Medicine "Report on the Personnel Needs and Training for Biomedical and Behavioral Research", Appendix Table B3, page 177

Examination of the specialties represented in the postdoctoral pool reveals that they do not contribute uniformly to the increase observed in Figure 1. Table 2 shows that five specialties have had a 48 percent increase in the number of postdoctoral positions between 1979 and 1983. These five specialties account for much of the increase in the entire pool. The majority of the basic sciences have not increased their numbers of postdoctorals. The five specialties that have grown encompass the new fields of molecular engineering, bacterial genetics, genetics and cell biology, where one would expect retraining or extended specialized training to occur.

Table 2

NUMBER OF BIOSCIENCE POSTDOCTORALS
WITH SELECTED SPECIALTY AREAS
1979 AND 1983

	Number of Postdoctorals		
Ph.D. Bioscience Specialty Area	1979	1983	% Increase
Selected Specialties	1,716	2,534	48%
Biophysics	101	184	
Botany	163	369	
Cell Biology	352	620	
Genetics	239	344	
Microbiology	861	1,017	
All other bioscience postdoctorals	5,175	5,883	13%
Total bioscience postdoctorals	6,891	8,417	22%

Source: National Science Foundation, Division of Science Resource Studies

In examining the sources of support for postdoctorals, for U.S. citizens only, the National Research Council found that 32 percent receive federal traineeships or fellowships specifically designed to support a period of training for the individual. Non-federal sources of support for postdoctoral training account for about 22 percent of positions and are from funds generated by a variety of industries and foundations. Most striking, at least 47 percent of postdoctorals are supported by research grants. These postdoctorals are hired as employees, although they are receiving training at the same time. There are two advantages to the use of research grants to support postdoctoral training. One is that people are being trained in those areas that are considered important research areas by peer review groups. The second advantage is that training tends to occur in the top institutions that are the most productive and research intensive. There is a disadvantage, however, in that this tends to be a self-perpetuating system, with training occurring in the branches of science that are the most active today.

The salaries and stipends for postdoctorals are not lucrative. The new NIH/ADAMHA postdoctoral fellowship scale ranges from $16,000 in year 1 to $23,000 in year 3 to $30,000 in year 7. The big jump after year 2 coincides with the end of housestaff training and is designed to provide the M.D. research trainee with a stipend from an NIH postdoctoral grant comparable to the one a resident gets as salary. In comparison to the lowest paid medical school assistant professors, whose salary scale begins in the upper twenties, a postdoctoral salary is much less. In fact, a postdoctoral candidate works for less than many other people. For instance, at Georgetown University a newly graduated bachelor, with a B.S. in chemistry or biology and with no special skills, can be hired as a technician for only $500 less than a Ph.D. with six more years of education and experience. A little thought reveals that the new minted Ph.D. is a great bargain and is one reason why there are so many postdoctorals on grants. It is far better to have a postdoctoral working on your grant than it is to have a technician because the postdoctoral is better trained, does more and better work, works weekends, and, best of all, can write. The one question is whether this is exploitation. The idea is to give training in return for work, which is good, but someone who is in a postdoctoral too long becomes a very poorly paid skilled employee, not a postdoctoral trainee.

Once a Ph.D. has completed the postdoctoral period, where does he or she go? Academic positions are one of the major job resources for Ph.D.s with postdoctoral training. Figure 2 illustrates the steady and sharp rise in the number of Ph.D.s employed in the biomedical sciences in colleges and universities, including medical schools, between 1960 and 1983. Figure 3 illustrates some

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of the changes that are occurring in the academic labor force. From 1973-1981 the number of postdoctoral employees rose sharply. This rise was paralleled by an increase in all academic ranks through 1978. The continued parallel increase for associate professors and professors suggests that associate professors will become professors in due time. Of interest and concern is the declining assistant professor pool, which suggests that entry level positions are decreasing.

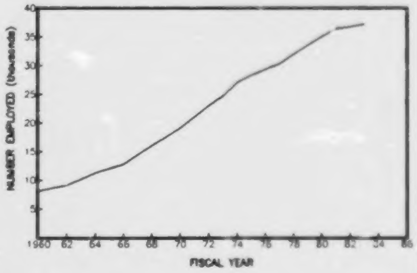

Figure 2: Depicts the number of Ph.D.s employed in the biomedical sciences at colleges and universities, 1960 – 1983

Source: Adapted from the 1983 Institute of Medicine "Report on the Personnel Needs and Training for Biomedical and Behavioral Research", Figure 3.8, page 73

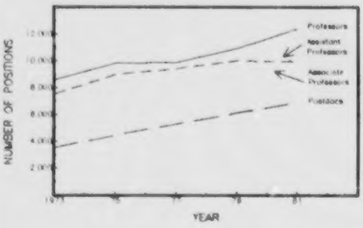

Figure 3. Illustrates the changing employment patterns of Ph.D.s in the academic labor force. The parallel rise in number of Ph.D.s in each academic job category is uniform except for the assistant professor category, suggesting a decrease in medical school entry level positions.

Source: National Research Council, from the 1973–81 Surveys of Doctorate Recipients

An increasing number of Ph.D.s are being hired in non-faculty, non-permanent positions of various kinds and are not entering the faculty mainstream. Table 3 shows the distribution of basic science and clinical science medical school faculties for 1972 and 1982. While there was an increase in the Ph.D.s in the basic science departments, the striking phenomenon was the increase in the number of Ph.D.s in the clinical science departments. Although this represents more participation of clinical departments in research activities, the situation raises special problems. The medical school clinical science departments are an unnatural environment for a Ph.D. Since he is not a clinician, he will have a career limited to being the head of research within a department rather than one as the head of the department, a different career than he might have anticipated. Such a person can and does get tenure; however, it is unclear how stable the fiscal support for such persons will be. If the clinical funds that are used to support the department's activities are reduced, the Ph.D.s are vulnerable to being replaced by clinical staff who can maintain the revenue base. It is also important to note in Table 3 the increasing "career age" of M.D.s in the basic sciences; that is, the number of years since the doctorate was obtained. The average career age of the M.D. in basic science is 24 years, which means that there are almost no M.D.s entering basic sciences any longer. In contrast, in the clinical departments the career age of the M.D.s and the Ph.D.s has not changed significantly. These data combine to suggest that the entire medical school research effort is becoming more and more dominated by Ph.D.s in both the clinical and basic science departments.

Table 3

CHANGE IN FULL-TIME FACULTY IN U.S. MEDICAL SCHOOLS BY DEGREE TYPE AND DEPARTMENT, 1972 AND 1982

	1972			1982		
Department	MD	MD/PhD	PhD	MD	MD/PhD	PhD
Basic Science						
Number	752	540	5,059	650	438	6,886
% of Total	11	8	76	8	5	83
Career Age*	19		10	24		13
Clinical						
Number	18,504	1,440	3,496	28,515	1,988	5,868
% of Total	72	6	14	73	5	15
Career Age*	15		9	17		11

** Career age represents the number of years since the doctorate was awarded*

Source: National Academy of Sciences/Institute of Medicine Committee on National Needs for Biomedical and Behavioral Research Personnel

To conclude, I would like to make a few points about the future. Figure 4 shows the number of postdoctoral Ph.D. training positions budgeted by NIH and ADAMHA. The number of postdoctoral positions funded by NIH/ADAMHA has been steady and is projected to remain steady for fiscal 1985 and 1986. If research grants are cut back, it will probably mean more opportunities for postdoctoral training under the remaining research grants because postdoctorals are a better bargain for the principal investigator than technicians. Thus the number of postdoctoral training positions should remain steady. The job market for Ph.D.s will be better because the faculty is growing older. The attrition rate of senior faculty is running about 1 percent per year, which is very small, but within 5 to 10 years that attrition rate is going to move up to 3 to 4 percent, at which point the system will be in balance and will stop growing. Then it becomes a question of maintaining a steady input. If the input declines, the job opportunities should expand. There are a number of indications that the input is going to decline. One is that the support for predoctoral training by the federal agencies has declined and is threatened with even further cuts, reducing the incentive for college graduates to go into predoctoral training. The second indication is depicted in Figure 5. The number of individuals receiving doctoral degrees has been steady, but as a fraction of the population it has been dropping. Clearly we are not producing the same proportion of highly trained scientists among our population as we did ten years ago.

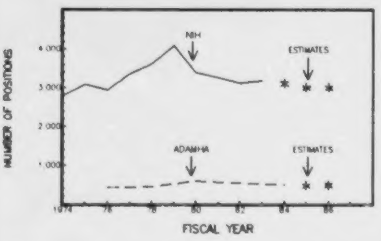

Figure 4: The number of budgeted postdoctoral Ph.D. training positions funded by ADAMHA and NIH. These are FTE positions not numbers of people which may be somewhat larger. Data for 1985 and 1986 are projected.

Source: National Institutes of Health and Alcohol, Drug Abuse, and Mental Health Administration, February 1985.

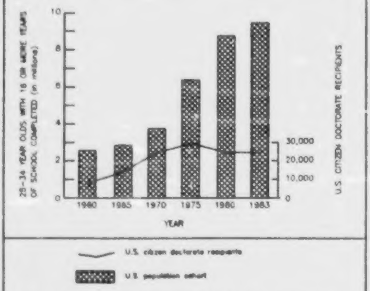

Figure 5: The decreasing number of doctoral awards as a fraction of the potential population. The bars represent the cohort of the U.S. population which is 25 – 34 years old with 16 or more years of school, in selected years from 1960 to 1983. The curve depicts the new Ph.D. recipients in each of the six years.

Source: National Research Council, Office of Science and Engineering Personnel, Doctorate Records File and U.S. Department of Labor, Bureau of the Census

Baccalaureate degrees awarded in this country from 1962 to 1982 are shown in Figure 6 and reveal a very worrisome trend. The number of B.A.s awarded yearly has been steady since 1976, despite the fact that the "baby boom" generation had passed age 21 by 1975. This stable output of B.A.s can be attributed to the enrollment of a larger percentage of a smaller age cohort in college, which is reassuring. However, within the pool of baccalaureate recipients, the number of bioscience bachelor's degrees has fallen precipitously. This is the pool of future bioscience Ph.D.s. There were some 37,000 bachelors degrees awarded in the biosciences in 1984. There were also the same number who took the medical school or dental school aptitude test. It appears that very few of the bioscience B.A. graduates wish to seek straight Ph.D. training; thus the number of those matriculating in Ph.D. programs has dropped very drastically. Because of this decline in the pool feeding the doctoral programs, the number of postdoctoral trainees will eventually decrease, even as the positions for postdoctoral training increase, in both the traditional and the new bioscience fields. My estimate is that by 1990 or 1995 there will be many job opportunities for Ph.D.s as new fields develop and many of us leave the fray to the younger people.

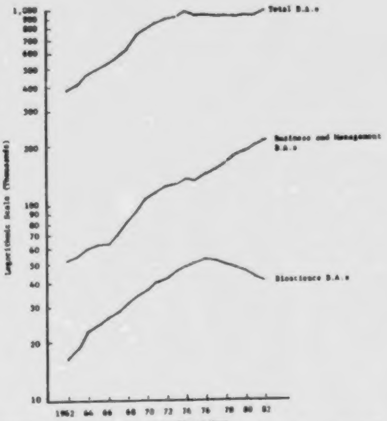

Figure 6: The changing pattern of baccalaureate degrees awarded from 1962-1982 in 2 disciplines. While total BAs awarded here have not increased since 1976, the share of those awarded in the biosciences has declined.

Source: National Academy of Sciences/Institute of Medicine Committee on National Needs for Biomedical and Behavioral Research Personnel

Thus there have been substantial changes in Ph.D. postdoctoral education in the past few years, and there will continue to be changes in both the training and employment opportunities for Ph.D.s in the biologic sciences in the years ahead. Both the interest in and the opportunities for postdoctoral training are increasing. About half of new Ph.D.s take a postdoctoral position, and this number is increasing as employment opportunities change. The size of the postdoctoral pool is growing because of many factors, including economic stringencies, the complexity of science, participation in large-scale research teams, and an increase in specialized training in new fields of research exploration. Postdoctorals are supported by modest stipends from research grants (47 percent), federal traineeships (32 percent), and non-federal fellowships (22 percent), for two to three years. Following postdoctoral training, an inceasing number of bioscience Ph.D.s are finding employment in colleges, universities, and medical schools, but not as regular faculty appointees. The increased number of Ph.D.s in clinical departments in medical schools is a new phenomenon and may lead to problems in future career development and economic instability in a changing fiscal atmosphere. However, because of the decline in the numbers of new bioscience Ph.D.s and decreasing interest in bioscience at the baccalaureate level, we must begin to be concerned about possible shortages in trained bioscientists in the future. Certainly the training and employment opportunities should be ample in the mid-1990s when the 1985 Ph.D. candidate entrants complete their doctoral education.

The Clinical Subspecialty Training of Physician Investigators

Harold J. Fallon, M.D.

Physicians who aspire to a research career must be properly trained not only in research but in the clinical component of their specialty discipline. The vast majority of these clinical investigators will seek a career in academic medicine and participate in teaching and patient care activities in their fields of expertise in synergy with their research work. To achieve the clinical expertise necessary to fulfill this role for most disciplines requires a minimum of five years of training after receipt of the M.D. degree. In the surgical disciplines primary board certification is not awarded until a trainee has completed a minimum of five years of postgraduate work in an approved residency. Usually the first two years are in general surgery and the remaining three or more are in either general or a specialty surgical discipline such as urology or orthopedics. In the non-surgical disciplines, the practice has arisen of awarding a primary board certification after the completion of three years of training. Such Board certified physicians may then enter practice in internal medicine, pediatrics, or family medicine as primary care physicians. However, future research faculty require additional clinical subspecialty training in fields such as nephrology or rheumatology to attain the level of specialty clinical competence necessary to their academic and research roles, and commonly will undertake a two- to four-year fellowship, during which subspecialty clinical and research training are both provided.

This paper will examine the sources of support for this clinical subspecialty component of graduate medical education. There is a paucity of information on fellowship support, with most of the available data derived from studies of manpower in the field of internal medicine. However, this subset of subspecialty fellows or residents is well worth examining since it is estimated that at least two-thirds of all clinical fellows are in the subspecialty fields of internal medicine. Accreditation Council on Graduate Medical Education (ACGME) statistics show that subspecialty board certification was awarded to over 31,000 individuals between 1974-1984; of these, 69 percent were subspecialty internists. In reviewing the available data on clinical subspecialty fellows in internal medicine, we will refer to the entire group of fellows; we do not have an accurate estimate of how many of these fellows enter academic positions and how many enter specialty practice in medicine.

I am indebted to several sources for the manpower data in this paper; they include Gerald S. Levey, M.D., chairman of medicine, University of Pittsburgh who has directed the National Study of Internal Medicine Manpower (NSIMM) for the last three years, Lynn Langdon of the American Board of Internal Medicine, Lynn Morrison of the Professors of Medicine, and Dick Nelson of the ACGME.

In internal medicine, all of the recognized subspecialties except general internal medicine currently require board certification. Table 1 lists the NASIMM data on the total number of internal medicine subspecialty fellows in 1983-84 by discipline. Note that there are twice as many cardiology fellows as in any other program; nearly one-quarter of all 7,025 fellows are in cardiology training. The large number of subspecialty fellows in internal medicine includes a substantial number of trainees who graduated from foreign medical schools. As shown in Table 2, presently 16 percent of fellows are foreign graduates of foreign medical schools and 4 percent are U.S. citizen graduates of foreign medical schools. Table 3 depicts those who completed subspecialty training and passed the certifying Board examination in the most recent two-year cycle ending in 1983. The total number of trainees who were foreign medical graduates (FMG) ranged from over 30 percent in nephrology and cardiology to about 15 percent in rheumatology and infectious diseases. Pass rates on the examination ranged from over 80 percent in the latter disciplines to 67 percent in cardiology. Clearly a large number of FMGs are in training for the U.S. subspecialty boards.

Table 1

FELLOWSHIP TRAINING BY FIELD IN INTERNAL MEDICINE 1983-84

Subspecialty	F1*	F2*	F3*	Total Fellows	#Programs
Allergy/immunology	68	62	19	149	47
Cardiology	774	731	230	1735	251
Critical care	78	28	0	106	29
Endocrinology	214	161	63	438	132
Gastroenterology	386	368	61	815	185
General internal medicine	83	50	37	170	24
Geriatrics	65	37	6	108	28
Hematology	66	40	17	123	41
Hematology/oncology	283	223	146	652	125
Infectious disease	222	197	68	487	130
Nephrology	262	247	65	574	141
Nutrition	17	11	5	33	13
Oncology	158	144	47	349	49
Pharmacology	46	35	6	87	33
Pulmonary disease	349	337	92	778	174
Rheumatology	194	182	45	421	116
Total	3,265	2,853	907	7,025	1,518

** F1, F2, and F3 refer to year of fellowship*

Source: Adapted from Schleiter, MK and Tarlov, AR. National Study of Internal Medicine Manpower IX. Internal Medicine Residency and Fellowship Training: 1984 Update. Ann Intern Med; 102:681–685.

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Table 2

COMPOSITION OF CLASSES IN INTERNAL MEDICINE FELLOWSHIP TRAINING ACCORDING TO MEDICAL SCHOOL ATTENDED 1982-83 AND 1983-84

	Year of Fellowship			Total+	
Type of Graduate*	F1	F2	F3	Number	Percent
1982-83					
USMG	2,464	2,095	569	5,128	79
US-FMG	108	78	15	201	3
FMG	565	453	129	1,147	18
Total	3,137	2,626	713	6,476	
1983-84					
USMG	2,608	2,272	742	5,622	80
US-FMG	124	128	18	270	4
FMG	533	453	147	1,133	16
Total	3,265	2,853	907	7,025	

** USMG = graduates of U.S. or Canadian medical schools; US-FMG = U.S. Citizens who graduated from foreign medical schools; and FMG = foreign graduates of foreign medical schools.*

+ 1,455 fellowship programs were surveyed in 1982-83 and 1,518 in 1983-84

Source: Adapted from Schleiter MK and Tarlov AR. National Study of Internal Medicine Manpower IX. Internal Medicine Residency and Fellowship Training: 1984 Update. Ann Intern Med; 102:681-685.

Table 3

CERTIFICATES AWARDED BY INTERNAL MEDICINE SUBSPECIALTY BOARDS FOR THE TWO-YEAR CYCLE ENDING IN 1983

		Total Number Trainees	
Subspecialty	#Certificates	% Pass	% FMG
Cardiology	1825	67%	33%
Endocrinology	353	70	29
Gastroenterology	865	79	27
Oncology	750	72	22
Hematology	400	66	29
Infectious Disease	370	82	14
Nephrology	568	68	36
Pulmonary	947	69	26
Rheumatology	421	81	15

Source: American Board of Internal Medicine

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What are the sources of support for these subspecialty fellowship programs? Nationwide, for clinical fellows in all the medical disciplines, the estimated sources of support for stipends and benefits for trainees in 1982-83, based on a survey of AAMC Council of Teaching Hospitals members, are shown in Figure 1. For internal medicine alone, the sources of support are given in Table 4. In the case of internal medicine, while general hospital revenues support over 70 percent of the stipends for internal medicine residents during their first three years of primary board training, only 39 percent of the stipends for clinical fellows came from this source in 1983-84. The VA and military hospitals were the second largest source of funding, providing 20 percent of total funds. Federal training grants, which provide laboratory or clinical research training for at least some of those destined for academic positions, provide only 11 percent of support for clinical fellows overall. This share of support is decreased from the 15.1 percent grant support of fellows available in 1976-77. Since these training grants are limited to support of the research component of training only, even those fellows who will enter academic research must be supported for the clinical subspecialty portion of their fellowship years by other sources of funds. Other sources of funding for fellows contribute only small percentages to the total support available nationwide. Faculty professional fees account for only 8 percent of support and private foundation grant only 6 percent. Clearly the major source of funding for these trainees, who care for patients as a major component of their activities, remains patient care revenues. In Table 4, based on estimates from chairmen of departments of medicine, the total expenditure for subspecialty training in internal medicine in 1983-84 was $165 million. Using these data we could make some extrapolations as to the total cost of subspecialty training. If internal medicine fellows are two-thirds of the total as we estimated earlier, then the total cost for subspecialty trainee stipends in 1983-84 in all disciplines might be estimated at almost $250 million.

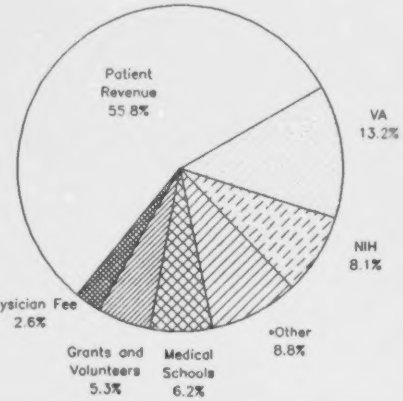

Figure 1: Nationwide sources of funding for clinical fellows stipends and benefits; 1982–1983.

** Includes state and municipal appropriations, federal agencies and endowments*

Source: COTH Survey of Housestaff Stipends, Benefits and Funding, 1983. Association of American Medical Colleges, Department of Teaching Hospitals.

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Table 4

SOURCES OF FELLOWSHIP STIPENDS IN INTERNAL MEDICINE 1976–77 and 1983–84

	1976–1977.		Converted to+	1983–1984.	
Sources	Percent	Dollars*	1983 Dollars*	Percent	Dollars*
Hospital revenue	33.0	29,666	51,916	39.0	64,552
State and local government	5.0	4,495	7,866	6.0	9,931
VA and military	20.8	18,698	32,722	20.0	33,104
Federal training grunts	15.1	13,574	22,754	11.0	18,207
Research grants	5.1	4,585	8,023	3.0	4,966
Professional fees	6.6	5,933	10,382	8.0	13,242
Medical school funds	4.6	4,135	7,236	4.0	6,621
Foundation training grants	5.7	5,124	8,967	6.0	9,931
Other	4.1	3,686	6,450	3.0	4,966
Total		89,896	157,318		165,519
Mean stipend/program		59	105		109
Mean stipend/fellow		15	27		24

* *Dollar amounts given in thousands, excluding fringe benefits.*

+ *Calculated from the change in annual consumer price indexes between 1976 and 1983*

. *Data for 1976–77 from Tarlov and colleagues and based on results of a survey of 1512 programs with 5,885 fellows. For 1983–84, 1518 programs with 7,025 fellows were surveyed.*

Source: Adapted from Schleiter MK and Tarlov AR. National Study of Internal Medicine Manpower IX. Internal Medicine Residency and Fellowship Training: 1984 Update. Ann Intern Med; 102:681–685.

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Table 5 lists each of the subspecialties in internal medicine and their particular source of revenue. Within internal medicine there are nine subspecialty boards. Neither general internal medicine nor geriatrics have subspecialty boards, but there are subspecialty training programs in these areas. There is a dramatic variability in funding sources from one subspecialty to another that would be hidden by only examining overall trends. For example, hospital revenues support training in cardiology and critical care in much greater proportion than they provide stipend support for training in geriatrics or endocrinology. Some subspecialties have an unusual distribution of funding source, such as geriatric training, where the VA provides more than half of the total funding for geriatric fellowships. The foundations tend to support non-traditional areas, such as general medicine, pharmacology and geriatrics. Federal training grants contribute substantially to support of fellows in some disciplines, particularly endocrinology and pharmacology. Clearly, subspecialty training is not a monolithic entity. The amount spent on training in 1983-84 varied from a high of $41 million in cardiology to a low of $0.7 million in nutrition.

Table 5

SOURCES OF FINANCING OF FELLOWSHIP STIPENDS BY SUBSPECIALTY IN INTERNAL MEDICINE

Subspecialty	Hospital Revenue	State & Local Government	VA & Military	Federal Training Grants	Research Grants	Professional Fees	Medical School Funds	Foundation Training Grants	Other	Dollar Amount*
Allergy/immunology	32%	24%	19%	7%	3%	5%	2%	6%	3%	$ 3,627
Cardiology	48	4	16	5	2	12	4	3	5	41,125
Critical care	75	0	7	0	2	6	2	6	1	3,383
Endocrinology	25	4	21	29	3	4	6	4	3	10,107
Gastroenterology	40	7	23	11	2	7	4	3	2	18,160
General internal medicine	47	7	5	4	0	4	5	26	2	3,928
Geriatrics	12	2	55	4	0	8	4	16	0	3,573
Hematology	45	12	8	15	0	6	1	13	0	2,935
Hematology/oncology	32	2	26	20	5	6	5	3	2	15,788
Infectious disease	38	5	23	13	7	2	4	6	5	11,168
Nephrology	43	3	18	11	2	10	4	5	2	13,315
Nutrition	34	7	13	24	0	10	9	4	0	709
Oncology	19	29	8	11	5	12	3	10	3	7,924
Pharmacology	5	3	8	29	10	0	6	32	8	1,999
Pulmonary disease	42	4	22	11	2	5	3	8	2	18,105
Rheumatology	37	5	19	13	3	3	5	12	3	9,808

* *Dollar amount given in thousands excluding fringe benefits.*

Source: Adapted from Schleiter, MK and Tarlov AR. National Study of Internal Medicine Manpower IX. Internal Medicine Residency and Fellowship Training: 1984 Update. Ann Intern Med; 102:681-685.

One of the biggest current concerns in internal medicine manpower projections is the large number of subspecialists being produced. The GEMENAC report has estimated that there will be excess numbers of practicing physicians in almost all of the medical subspecialties by 1990. This is true for some of the surgical specialty disciplines as well. Of interest, is the decline in the percent of all internists who pursue subspecialty training from a high of 75 percent in 1976 to around 60 percent in the last two to three years. This trend has paralleled a trend for the increasing numbers of women entering internal medicine to choose general internal medicine; whereas male trainees more frequently pursue further subspecialty training.

The trends toward participation of FMGs in clinical subspecialty training are also important to note. Almost 85 percent of alien FMGs completing an American internal medicine residency enter subspecialty training, while for U.S. graduates the total is 63 percent. U.S. FMGs have the lowest rate of subspecialization after general medicine residency at 23.4 percent. These figures are contrary to the conventional wisdom. The factors that lead FMGs to seek subspecialty training, such as personal career goals, U.S. hospital placement, or other factors are still undetermined. We do know that to participate in a subspecialty training program leading to board certification in the United States, one must have trained in a domestic internal medicine residency program so this group does not represent an influx of further foreign graduates using fellowships as a point of entry into the system. Nonetheless, the interest of FMGs in subspecialty training is a fact that has cost implications and political implications if one is beginning to think about ways to reduce the supply of subspecialty manpower.

Overall, while the numbers of subspecialists practicing internal medicine in the U.S. will remain high, the numbers of generalists is increasing and the percent of subspecialists is expected to gradually decline. Whether this trend is a reflection of the greater numbers of women entering medicine, is due to a restriction on the number of subspecialty training positions, or is a response to a general awareness of the GEMENAC predictions of oversupply is not known.

Another trend of importance in estimating the total manpower pool is to examine how many first year fellows complete a second year and even a third year of fellowship. Tables 2 and 3 reveal that almost 90 percent of those completing the first year (F1) will complete the F2 year and thereby become subspecialty board eligible. In addition, a substantial number of fellows, almost 32 percent in 1983-84, stayed on for a third year, up from 14 percent in 1977. An increasing number are even electing a fourth year of fellowship. While one might expect that these highly trained subspecialists are the subset who will seek academic positions and begin careers as clinical investigators, there is not a one-to-one correspondence between the numbers of these advanced trainees and the numbers entering academic positions in medicine. The demands of subspecialty practice in medicine are increasing so rapidly that many trainees believe that additional years of fellowship experience are necessary prior to entering a practice career as well as a research career. It would be interesting to investigate the career outcomes of these advanced clinical fellows and also to examine the sources of support for these third and fourth year fellowships as contrasted with the present data (Table 4) which mostly reflect funding for the large numbers of trainees in the F1 and F2 years required for specialty board eligibility.

Finally it is important to examine one trend that I think will have an impact on the future distribution of internists between subspecialists and generalists. That influence is the recent action of the Internal Medicine

Residency Review Committees (RRC-IM) to accredit subspecialty training programs. Subspecialty programs have never been accredited in internal medicine, although this has been the practice in surgery. The development of accreditation guidelines has been slow due to the large number of subspecialty programs (1,400 with an average of 2 people per program), the evolution of the various subspecialties, and the process of developing agreement between the nine subspecialty programs and the RRC-IM. The seven major stan-dards that the Residency Review Committee now requires of subspecialty training programs are:

1. Association with an approved general medicine program
2. Adequate faculty and time commitments
3. Adequate patient material for teaching
4. Adequate procedures and facilities
5. Structured curriculum
6. Peer interaction
7. Exposure to research

First, the subspecialty program must be associated with an approved general medicine training program. There are a number of free-standing hematology, oncology, and cardiology programs that do not meet this requirement. Second, there need to be adequate faculty and faculty time commitments. Many programs have been apprenticeship systems and do not meet minimum standards in that area. Third, there needs to be an adequate patient mix for proper teaching in the subspecialty, which is a problem in some hospitals. Fourth, procedures and facilities must be adequate. This requirement has had a big impact because hospitals are no longer doing all the things necessary to sustain an acceptable subspecialty training program. It is also a requirement that approved, accredited subspecialty training programs in internal medicine have access to clinical or basic research activities. As a result of these subspecialty accreditation requirements the number of internal medicine training slots in subspecialties can be predicted to decrease, although that is not the objective of the certification process which is designed to certify minimum quality standards. If a decrease in subspecialty training positions occurs by this accreditation review, it will further contribute to the desired overall decline in subspecialty manpower in Internal Medicine. Also, current proposals to restrict Medicare funding for graduate medical education to primary board certification would have a drastic impact on the production of medical subspecialists. We must, under these changing circumstances, identify and defend the sources of support for the vital clinical subspecialty component of the training of future academic research physicians as well as replacements for the necessary number of clinical subspecialists. Academic physicians will need subspecialty clinical competence to fulfill their roles as tertiary care physicians in the academic setting and to enable them to identify and pursue those research problems of greatest clinical relevance to their disciplines. While many forces can be predicted to conspire to reduce the proportion of subspecialists in practice, we must be concerned to preserve the resources necessary to train clinical investigators.

Support for Graduate Medical Education

Research Training for Clinicians

Doris H. Merritt, M.D.

One of the major recent concerns of the National Institutes of Health has been the decrease in the percentage of clinicians serving as principal investigators on research grants. In fiscal 1972 31.3 percent of new research project grants (R01s) were awarded to first-time applicants with clinical degrees. Of these 6.4 percent were M.D./Ph.D.s. In fiscal 1982 this total figure dropped to 20.2 percent of whom 5.2 percent were combined M.D./Ph.D degree holders. These figures do not account for clinical investigators receiving support through program project grants and centers. Nonetheless, the R01 represents a critical portion of NIH funding. None of us pretend to know what the ideal percentage of M.D.s in the new R01 applicant pool should be, but we are probably agreed that it should not be zero. The decreasing number of physicians in research training programs through 1980 supports the pessimistic view that M.D.s will continue to decrease as principal investigators for some time. It was because of these trends and the implications of the decrease in trained investigators to conduct future research requiring the special insight of the clinician that Dr. Wyngaarden, in 1978, focused on the "endangered species". Subsequent addresses by the presidents of various academic societies fueled the ensuing national discussion and, thus, the emphasis on research training for clinicians.

This paper will briefly review research training for clinicians, both that provided through the National Research Service Award (NRSA) program, and the more advanced Career Development Series.

A common way to describe the NRSA program is in terms of institutional and individual awards. Table 1 shows the NRSA research training programs supported by each of those mechanisms for predoctoral and postdoctoral levels of training. By statute, the number of NRSA individual awards can account for no less than 15 percent of the yearly NRSA appropriation.

Table 1

NRSA MECHANISMS

	Level of Training	
	Predoctoral	Postdoctoral
Institutional Awards		
Institutional Research Training Grants	X	X
Medical Scientist Training Program	X	
MARC Honors Undergraduate Program	X	
Short-Term Training: Health Professional Schools	X	
Summer Pulmonary and Hypertension Research	X	X
Individual Awards		
Postdoctoral Fellowship		X
Senior Fellowship		X
MARC Predoctoral Fellowship	X	
MARC Faculty Fellowship	X	X
Cancer: Nurse Oncology	X	

As shown in Table 2, there has been a significant shift in the predoctoral portion of the NRSA program since 1977. Special programs such as the Medical Scientist Training Program (MSTP) have come to represent an increasing share of the allotted predoctoral positions.

Table 2

NRSA PROGRAM DISTRIBUTION as a PERCENTAGE OF POSITIONS

	1977	1980	1983
Positions	10,198	10,664	10,570
Predoctoral	44%	37%	36%
Postdoctoral	50%	52%	50%
Special Programs	6%	11%	14%
MARC	(1.3%)	(3.0%)	(4.6%)
MSTP	(4.9%)	(6.2%)	(6.4%)
STT:SHPS		(2.0%)	(2.8%)

Figure 1 depicts the numbers of individuals in the NIH research training program for the ten years since the NRSA legislation was passed and all previous research training authorities abolished. All individuals who received appointments are counted, including those of less than 12 months duration. The number of individuals is, therefore, higher than the actual obligations for full-time training positions generally reflected in budget tables.

Figure 1

INDIVIDUALS IN NIH NRSA RESEARCH TRAINING PROGRAMS, 1974-1983

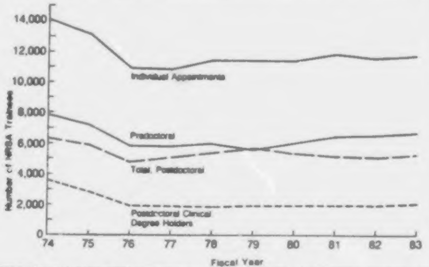

Figure 1: Total NRSA trainees each fiscal year. Initial high point reflects simultaneous existence of 3 training programs: TOIs, Weinburger awards, and new NRSAs.

The large number of individuals supported in 1974 is a result of the release of impounded 1973 funds and the simultaneous existence of three training programs: the old T01s, the Weinburger awards initiated after the T01 program was abolished, and the newly introduced NRSA awards. By 1976, the T01s and Weinburger commitments essentially were fulfilled, and from that time on the number of individuals in research training under the NRSA has been remarkably constant. This stability was achieved only through vigilant efforts on the part of many. Each year between 1978 and 1985, the administration sought to cut the NRSA training program, and each year the Congress passed an appropriation for NRSA sufficient to maintain the program at the previous year levels. The fiscal 1986 budget represents the first time in the past eight years that NRSA training has not been an element of contention requiring congressional remediation.

The decline in the numbers of predoctoral trainees, which includes the Minority Access to Research Careers (MARC) program and the Medical Scientist Training Program (MSTP), resulted from the failure of the training appropriation, in 1979 constant dollars, to increase in the face of increasing tuition, and the addition in fiscal 1980 of a new program, Short-Term Training for Students in Health Professional Schools. Approximately 900 students participated in the Short-Term Training program in 1980. The stability of the predoctoral training program is expected to continue in fiscal 1985, with a possible modest decrease in the total number of predoctoral students, reflecting the effect of continuing increases in tuition. However, the loss of some 250 to 300 predoctoral students, while only a three percent drop in the total NRSA program, would represent a decline of almost ten percent in the predoctoral training program.

The total postdoctoral training pool has remained relatively constant since 1976. However, because the number of clinicians in research training had become so small and clinicians continued to disappear from the group of first-time principal investigators, research training for clinicians began to be considered a critical problem in 1978. Figure 2 shows the trends from 1974 to 1983 in the number of clinicians in training programs. The postdoctoral clinical trainees reached a nadir in 1978 and began a very slow rise to 2,113 trainees by 1983. This is approximately the number recommended in the 1983 NAS report on the National Needs for Biomedical and Behavioral Research Personnel. The Medical Scientist Training Program (MSTP) increased its appointments from 451 students in 1974 to 677 in 1983. This six year program is considered one of NIH's most successful in training clinical investigators. Seventy percent of the MSTP graduates hold positions in academic medicine doing research and training other physicians. The program was able to fund 682 students in FY 84 and will fund the same number in FY 85. It will be strengthened to support approximately 725 students per year, as soon as funds permit, at which point it will support more than 100 M.D./Ph.D. graduates per year. These scientists are currently competing most successfully for R01 research grant support. The Short-Term Training for Students in Health Professional Schools is an extremely popular program reintroduced in fiscal 1980 following a change in the NRSA payback obligation. This training program is expected to continue to support approximately 1,200 students a year. NIH estimates that in fiscal 1984 and 1985 the pattern for initial research training of future clinicians will not change appreciably from that shown for 1983.

Figure 2

INDIVIDUALS IN NRSA PROGRAMS FOR CLINICAL INVESTIGATORS, 1974-1983

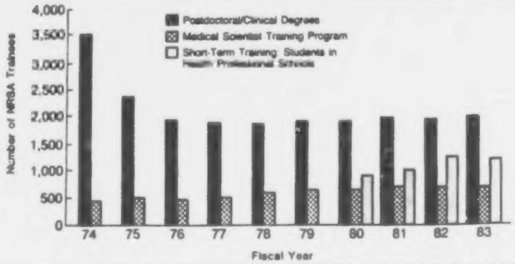

Figure 2: Depicts clinicians in the NRSA postdoctoral training programs.

There have been some new directions in the NRSA program. There is convincing evidence to show that the student who interrupts medical school for a year of research training is likely to elect a research career. Training program directors have been encouraged, with the prior approval of the NIH program administrator, to consider using available stipend money to offer a year of research training to medical, dental or veterinary students; one postdoctoral stipend can support two such trainees at the predoctoral level.

A further NRSA program is being introduced by NIH. The National Health Service Corps program supports medical students with tuition and salary in exchange for a service obligation. This NHSC service obligation can be met by service in research. However, prior to 1981, only those students who received an individual NRSA award could convert their service obligation to a research payback obligation. In 1981, the Congress modified the law to permit research training on an institutional training grant to serve as the bridge from an

NHSC service obligation to a NRSA research obligation. Almost 200 such appointments have since been made to the institutional training programs around the country.

In order to attract NHSC M.D. graduates to NIH for research training, a special intramural NRSA program was begun in fiscal 1985 under the direction of Dr. Edward Rall. Five NIH Institutes -- National Heart, Lung and Blood Institute, National Institute of Arthritis, Diabetes, and Digestive and Kidney Diseases, National Institute of Allergy and Infectious Diseases, National Institute of Child Health and Human Development, and the National Institute of Dental Research -- plus the National Institute of Mental Health in ADAMHA are particpating. The program will accept approximately 20 new trainees a year for a three-year enrollment under NRSA rules and regulations. National Health Service Corps students are given first priority for appointment.

The importance of more and better quality training for our future physician-scientists cannot be overemphasized. Recent analyses by the NIH indicate that the more time M.D. postdoctoral trainees spend in training, the more likely they are to apply for and receive an NIH R01 research grant. Our data show that when the length of supported research training is 12 months or less, only 20 percent of such M.D. trainees apply for an R01 grant and 50 percent of these applicants are successful. By contrast, 43 percent of those who received NIH supported research training for 30 months or longer apply for R01 grants and 70 percent of these applicants are successful. In general, M.D. recipients of individual fellowships are more successful than those trained on institutional grants, but this may merely reflect their greater duration of research training. While NIH has only been able to analyze data on R01 grantees and not all M.D. investigtors participating in NIH sponsored research, this improvement in R01 award rate from 10 percent to 30 percent of former trainees, which is associated with extending the training period beyond 30 months, has led us to conclude that M.D.s have fallen behind in competing for R01s chiefly because of inadequate research training.

As a result of these findings, Dr. Wyngaarden convened a seminar in June 1984 to review the current program guidelines for the NRSA institutional training grant to assure that the mechanism was being used to the best advantage for the research training of physicians. Recommendations from that meeting were promulgated in November 1984. All program directors were advised that NIH is reemphasizing certain elements of the guidelines and in particular would like all research trainees to commit themselves to an initial minimum investment of two years of research training, during which not less than 80 percent of their time is devoted to research. The NIH is particularly interested in eliminating the ambiguity between training for research and finishing subspecialty clinical training, for which many of these grants have been improperly used in the past. In addition, the guidelines stress a stronger basic science component. For those trainees who are initially successful and promising, the NIH recommends an additional two or three years of research training. As a result of these initiatives, the NIH hopes that M.D. trainees will become better prepared to compete for research grants of the R01 type.

The fiscal 1985 appropriation contained a substantial increase of funds for research training, which was earmarked for increased stipends. These increases, as shown in Table 3, were aimed primarily at making the income of the clinical postdoctoral trainee comparable to housestaff salary and thus more attractive to physicians. Equity was maintained for the postdoctoral Ph.D. who, after two years of postdoctoral training, is contributing in an important way to research activity.

Table 3

NRSA POSTDOCTORAL STIPENDS COMPARED WITH HOUSESTAFF SALARIES

Years of Relevant Experience	NRSA Stipend FY 1985	Housestaff Salary 1984-1985
0	$15,996	$20,808
1	17,004	22,202
2	21,996	23,450
3	23,004	24,660
4	24,000	25,847
5	26,004	27,115
6	27,996	
7 or more	30,000	

Predoctoral stipends were also increased, to $6,552 a year. This stipend was not meant to compete with the National Science Foundation stipend of $11,500. The NIH has traditionally looked upon the predoctoral stipend as assistance and not total subsistence. On the other hand, the cost per predoctoral student per educational institution is essentially the same as for NSF because the NIH, at this time, supports full tuition and the NSF contributes only $6,000 to tuition and other training related expenses. Because the increases in tuition over time will diminish the number of predoctoral trainees that can be supported under the NRSA, a group of representative university presidents, deans of graduate schools, and research training program directors were invited to meet at NIH in July 1984. After considerable discussion, these advisors agreed that NIH should utilize for tuition the model in effect for many years for managing salary increases for research personnel in the successive years of a research grant. That is, NIH will pay an increase of only 6 percent per year over the tuition charged in the original or competing year of the award. Flexibility to rebudget funds will be encouraged by NIH with the assurance that program directors will do everything possible to maintain the maximum number of trainees. The variation in budgeted positions for NIH trainees and fellows and actual dollar obligations for the NRSA program since 1974 is shown in Table 4. While it would appear that NIH has reduced the number of positions in 1985 by 600, the number of full-time positions will eventually exceed this estimate by some three to six percent due to prudent budgeting. For example, the 10,514 trainees shown for 1984 began as an estimate of 9,863.

Table 4

NIH SUPPORTED TRAINEES AND FELLOWS

Year	Dollar Obligations (in thousands)	Full-Time Training Positions	
1974	$186,489	13,341	Impoundment Release NRSA Act
1975	154,875	12,272	Stipend Increase
1976	119,998	9,654	
1977	127,458	10,196	
1978	143,926	11,123	
1979	143,661	11,197	
1980	178,388	10,664	Stipend Increase
1981	175,172	10,696	
1982	150,474	10,406	Allowance Cut
1983	164,654	10,570	Stipend Increase
1984	166,462	10,514	
1985*	217,943	9,891	Stipend Increase
1986*	217,943	9,891	

* Estimate

The current options for advanced research preparation offered by the Research Career Development, or K, series are shown in Table 5. It omits any reference to the Research Career Awards, which were lifetime awards designed to stabilize research faculty positions. These were discontinued, except for commitments, in 1964. The oldest of the K series is the Research Career Development Award (RCDA). These are used solely for salary and fringe benefits and were meant originally to follow the postdoctoral fellowship. After one five-year renewal, the RCDA was to be followed by the Research Career Award. Without the Research Career Award option, the RCDA has become less of a development award and is used more for junior faculty support. More than 80 percent of present holders of the Research Career Development Award now have R01 support. All NIH institutes support the RCDA, although some require an active R01 for eligibility.

Table 5

NIH RESEARCH CAREER DEVELOPMENT AWARDS

	NIA	NIAID	NIADDK	NCI	NICHD	NIDR	NIEHS	NEI	NIGMS	NHLBI	NINCDS	DRR	NLM
Research Career Development Award (K04)	X	X	X	X	X	X	X	X	X	X	X	X	X
Academic Investigator Award (K07)	X	X		X						X			
Clinical Investigator Award (K08)	X	X	X	X	X		X			X	X		
Mid-Career Development Award (K07)							X						
Special Emphasis Research Career Award (K01)	X											X	
Dental Scientist Award (K15)						X							
Physician Scientist Award (K11)	X	X	X		X	X	X	X		X			

The rest of these awards have two elements in common. They provide a salary of up to $40,000 plus applicable fringe benefits and are available only to

U.S. citizens. The actual salary is to be comparable to that of others at the same institution who are at the same level of training and experience.

All awards are not made by all institutes. Each institute, with advice from its National Advisory Council, selects the mechanisms that best meets its unique mission objectives. Furthermore, the details of the award are institute tailored for targeted results. As a result, the degree of the applicant (M.D. or Ph.D.), the extent of prior experience, the duration of the award, and the provisions for additional research support vary from institute to institute. There is no doubt that the choice of the appropriate award may be both confusing and frustrating for applicants, particularly if what appears to be the most applicable award is not available in a particular scientific area.

The Academic Investigator Award is designed to support the individual's own research career development but carries a strong element of institutional commitment to curriculum development to improve the environment for research. The Clinical Investigator Award is generally meant for those who have completed clinical training and do not want an extensive laboratory experience, although laboratory experience may be supported by this mechanism. Only the National Institute of Environmental Health Sciences designates a Mid-Career Development Award because they are seeking the expertise of individuals from other disciplines. The Special Emphasis Research Career Award is supported by the Division of Research Resources for veterinarians who wish to become laboratory animal scientists and by the National Institute on Aging to develop the capacity for multidisciplinary research in specific areas related to the social and behavioral sciences. The Dental Scientist Award for dentists with a strong commitment to oral health research will be initiated in fiscal 1985. The Physician Scientist Award is designed to provide the awardee with five years of phased supervised research development with a strong emphasis on basic science experience before undertaking work at a more independent level. As with all other awards in the K series, it is intended to provide support during transitional years until the awardee can establish a personal research program.

The degrees held by individuals in the Research Career Development series are illustrated in Figure 3 for the years 1977, 1980, and 1983. The number of M.D.s is approaching parity with the number of Ph.D.s, especially since the implementation of programs to promote clinical research. The 1984 pattern for the Research Career Development programs will show a slight increase in the number of M.D.s with the introduction of the Physician Scientist Award, which, in its first year was used to support 37 individuals on individual awards and two individuals on each of three institutional awards. The number of M.D. awards can be expected to increase slightly in 1985 as the clinical programs reach full strength. It is the intention of NIH to maintain a 50-50 ratio of M.D.s to Ph.D.s.

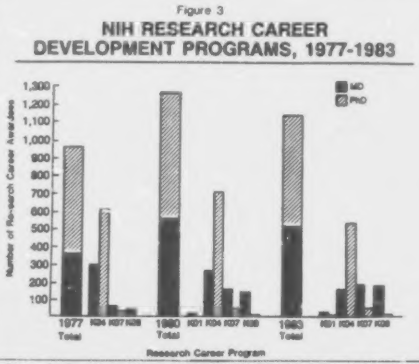

Figure 3

NIH RESEARCH CAREER DEVELOPMENT PROGRAMS, 1977-1983

Figure 3: Represents the degrees held by individuals awarded a Research Career Development award. The initial column depicts the total awardees, the following slimmer bars distribution of program awards. See Table 5 for identification of K-series award program.

The immediate future for the K series can be seen in Table 6. The budget history of the Research Career Development series, including the RCA (of which 60 were still active in 1984), shows that the funding remained essentially level from 1979 to 1983 with a consequent loss of purchasing power until fiscal 1984. In FY 85 the Congress injected considerable support, primarily for physician scientist training. The drop in the estimate for 1986 is occasioned by the need for the institutes to respond to program demands in other budget categories.

Table 6
RESEARCH CAREER DEVELOPMENT AWARDS

Year	Dollar Obligations (in thousands)	Number of Awards
1979	$48,924	1,339
1980	49,506	1,344
1981	50,492	1,252
1982	50,736	1,236
1983	50,284	1,187
1984	53,645	1,208 **
1985 *	75,081	1,335
1986 *	74,083	1,284

* Estimate
** Salary Ceiling Raised

Finally, a word about other opportunities in the NIH Intramural program for the young clinician. The newest program at NIH is a joint project with the Howard Hughes Medical Institute (HHMI). This program will support up to 30 medical students a year working with leading NIH intramural scientists on the NIH campus for periods of nine months to one year. With only three months to advertise the program, NIH received 66 applications for the first deadline, February 1985. The NIH also offers clinical electives in 12 subjects for medical students during an 8 to 10 week self-financed experience. In 1984, 175 medical students took advantage of this program. Another option for medical students is a research fellowship program during the summer months. The number of positions varies with available resources, which in 1984 were sufficient for 97 students.

In conclusion, the NIH has sought, through the NRSA program and the Research Career Development Awards program, to enhance the nation's capability to conduct scientific research. The NRSA program provides equal numbers of predoctoral and postdoctoral training positions, directly to individuals or to eligible students through educational institutions. The number of individuals trained under the NRSA program has been remarkably constant, despite annual administration efforts to cut the budget. The decline in the number of physicians in research training has been addressed vigorously since 1978 with a combination of programs at all levels of training, and it appears to have at least leveled off.

Strategies to correct the loss of physician-scientists include emphasizing postgraduate research training lasting at least two years, stressing the basic science component, and increasing the NRSA stipend to a level comparable to housestaff salaries. Advanced research training is accomplished through the K series or Research Career Development awards. These awards are intended as a bridge between postgraduate fellowships and established faculty investigator positions. Although the program is small, it provides an important first step for promising young investigators.

APPENDIX 6

American
Psychological
Association

TESTIMONY OF

Michael S. Pallak, Ph.D.

Executive Officer

American Psychological Association

on behalf of the

AMERICAN PSYCHOLOGICAL ASSOCIATION

before the

TASK FORCE ON SCIENCE POLICY

COMMITTEE ON SCIENCE AND TECHNOLOGY

U.S. HOUSE OF REPRESENTATIVES

on the subject of

SCIENCE AND ENGINEERING EDUCATION

July 9-11, 23-25, 1985

Honorable Don Fuqua, Chair

1200 Seventeenth St., N.W.
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Mr. Chairman and members of the Committee, I am Dr. Michael S. Pallak, Executive Officer of the American Psychological Association (APA). I am pleased to be representing the 76,000 members of APA and thank you for the opportunity to comment on U.S. science policy and the federal government's role in this area, especially as it relates to graduate education in science and engineering. We would like to commend the Task Force and the Committee for initiating this study and addressing the many issues crucial to the conduct of scientific research. In particular, we are pleased that the Task Force has expressed a special concern for the unique and critical role of the social and behavioral sciences.

Our testimony today focuses on three major points:

> The social and behavioral sciences, and in particular psychology, have made major contributions to a variety of areas, including those explicitly identified in the Task Force's report. Examples include insight into how behavior affects our risk of experiencing a heart attack, the impact of microcomputers on the education of our children and the structure of the family, and the effectiveness of large-scale government-funded social programs in achieving their stated objectives.
>
> Despite this impressive record, the social and behavioral sciences are frequently overlooked in discussions and policy related to science and engineering. In fact, the majority of oral testimony on scientific and engineering personnel presented at these hearings did not mention the social and behavioral sciences. More important, the social and behavioral sciences

have suffered deep and inequitable cuts in the levels of federal support for research and research training during the past five years.

Solving the major problems facing us today, whether they concern the advent of home and office automation or the costly and debilitating effects of alcoholism and drug abuse, require a better understanding of human nature. This mandates active federal support and commitment to funding social and behavioral research and to supporting the production of new scientists capable of attacking these problems.

The Role of the Social and Behavioral Sciences

The social and behavioral sciences are the group of disciplines that study human behavior and thought as they occur at the individual, organizational, and societal levels. There are few national problems which do not demand an understanding of human nature for their resolution. Social and behavioral factors are key to such diverse concerns as preventing cardiovascular disease, ensuring high quality teaching in the schools, understanding how the behavior of the individual consumer shapes the economy, and designing new technology which is compatible with the capabilities of its human operators.

Psychology is unique among the social and behavioral sciences inasmuch as it embraces not only a clear scientific perspective but also a strong service emphasis. The substantial training which psychologists receive in both theory and research methodology makes them in high demand by a variety of employers. In fact, few doctoral psychologists are unemployed; in 1982, the unemployment rate for all doctoral psychologists was less than 1%, and the corresponding rate for new doctorates was only 2% -- rates much lower than those for other social scientists. Moreover, the majority of those who are employed hold jobs that are psychology related and commensurate with their training and experience.

Currently, psychologists not only work in their traditional roles as faculty in psychology departments and practitioners in VA hospitals, community mental health centers, and health maintenance organizations but also serve in a variety of innovative roles: as researchers in both basic science and clinical departments in major medical centers; as faculty members in graduate schools of business and management; as behavioral toxicologists in federal research laboratories; as research methodologists and policy analysts in government agencies such as the National Institutes of Health and the General Accounting Office; and as human factors engineers in industry and the Department of Defense. As such, psychology is well positioned to contribute to both the development of basic scientific knowledge and the application of that knowledge to human and social problems. There are few areas in either human services delivery or research and development that are not subject to the concepts, methods, and practices of contemporary psychology.

Federal Support for Research Training in the Social and Behavioral Sciences

Basic and applied research in the social and behavioral sciences plays a much clearer and more instrumental role in American institutions than it is typically given credit for. Yet, during the last several years, the major research agencies such as NIH and ADAMHA have had budgets that barely meet inflation or in fact inflicted severe funding cuts for research training in the social and behavioral sciences. Since 1975, total doctoral and postdoctoral awards for research training in the behavioral sciences decreased by 50%. Particularly hard hit has been doctoral research training. In 1975, the number of doctoral awards in the behavioral sciences totaled 1,795 -- by 1982, this number had declined by 71% to 516.

This erosion was partly in response to earlier recommendations made by the NAS Committee on Personnel Needs and Training in the Biomedical and Behavioral Sciences. This group had advocated a radical shift of federal support away from doctoral to postdoctoral training, given concerns over shrinking academic demand for behavioral science faculty. However, in 1983, the Committee re-evaluated this recommendation in light of the significant research problems requiring attention, the growing nonacademic labor market for behavioral science investigators, and the unique and significant role that doctoral training plays in the production of behavioral science researchers. Its most recent report calls for a doubling of behavioral science researchers trained at the doctoral level and a steady increase of postdoctorally trained behavioral researchers. Specifically, the NAS Committee recommended that the number of federal doctoral awards be increased to the 1981 level of 650 and the number of postdoctoral awards to 540 by 1987. Award figures for 1984 reveal that this recommendation is far from being achieved; for NIMH alone, the agency which provides at least two-thirds of the training support for the behavioral sciences, only 212 doctoral and 219 postdoctoral awards were made.

This problem of declining research training support in the behavioral sciences has been further exacerbated by the fact that funding for behavioral and social science research has been seriously reduced during the last five years. For example, at the National Institute of Mental Health, the percentage of monies going to psychology has not increased since 1980. Moreover, a three-year ban against research related to major social problems was only recently lifted at NIMH, with the adverse effect of dissuading investigators from submitting research grant applications. Such lack of support for behavioral and social science research further erodes doctoral and postdoctoral research training by decreasing other mechanisms of training support (research assistantships and associateships) and opportunities for "hands-on" research experience with established investigators.

Although the NAS now recommends significant increases in behavioral sciences research training, little progress has been made in increasing federal support for doctoral training in the behavioral sciences and, quite frankly, damage has already occurred. Since 1975, the median time to complete a PhD has increased in psychology and the social sciences by almost a full year. The development of innovative doctoral training programs in such areas as health psychology and cognitive sciences has been handicapped because departments are finding it difficult to obtain the resources needed to mount new initiatives. We also are seeing decreases ranging from 18-50% in the number of new researchers graduating from programs in certain areas of psychology -- experimental psychology, personality, social psychology, and physiological psychology. As a result, the present and future supply of talented behavioral science researchers has been adversely affected, primarily in those areas which have the most to contribute to new and emerging problems facing us today.

New and Emerging Areas Requiring Attention

The lack of federal support for social and behavioral science research and research training is particularly troublesome, given that there are several new and emerging areas which urgently require the attention of behavioral and social science researchers. These include: health and behavior; aging; the design and adoption of new technology; and education. Many of these areas have consistently been identified by the general public as major social problems. For example, in the last major public opinion poll on science and technology, "helping older people" ranked first and "improving education" fourth out of 11 areas for increased spending. In addition, when asked to indicate scientific areas for increased funding, given a constant federal budget, disease-specific medical research and human learning process research ranked first and second of the 12 areas queried. As mentioned above, these are areas which have greatly benefited from social and behavioral science research but suffered in terms of federal support for these activities.

Health. The next major step in improving the general health of the U.S. population is not a medical one but a behavioral one. The Surgeon General's 1982 report "Healthy People" examines the 10 leading causes of death in the U.S. and concludes that seven of these are in large part behaviorally determined and could be substantially reduced by changing behaviors.

Much new work is needed in this area. In the area of cardiovascular disease, for example, not only is neurobiological research needed to link physiological events with their behavioral manifestations, e.g., the effect of brain peptides on behavior, but research is needed as well on such intangibles as how a patient's perceptions of the quality of life after a medical intervention affects their health and recovery -- an area vividly illustrated by artificial heart surgery.

In the area of mental health, the National Academy of Sciences has identified the critical research needed in determining the causes of schizophrenia, childhood mental disorders, and alcoholism -- problems which are so chronic and costly that even small advances in theory and application could be significant and cost-effective. Many of the questions on how our neural systems develop and function and their effect on behavior fall under the purview of not only the biomedical sciences but also physiological psychology and psychopharmacology. In addition, social and behavioral science research is needed to address such questions as the epidemiology of women, children, and teenage alchohol abusers and the path of normal childhood development so as to be able to detect mental problems earlier before they become more serious disorders.

Aging. Psychological research has contributed much to determining what are and what are not age-related differences. For example, recent efforts have found that in the past these differences have been exaggerated and in fact personality characteristics remain relatively stable and intellectual decline, barring poor health, does not being until the mid-80's. These findings provide new insight into such major problems as the prevention and treatment of Alzeimer's disease, the design of interventions for real losses that occur with age, and ways to replace societal values and measures which are biased against the aged.

Design and adoption of new technologies. While human factors is typically viewed as "which ways knobs should turn and where to place a handle," the most pressing human factors questions today tap such underlying psychological issues as how people process information and make decisions, especially when exhausted or under severe types of stress. The need for basic and applied human factors research is most dramatically illustrated by the importance of identifying human problems in designing the new weapon systems. Technological advances in weapons are now outstripping boudaries of human ability, with the result that the Pentagon wastes at least tens of millions of dollars a year designing technological wizardry that ignores the physical and psychological limitations of people who have to use and repair it. For example, there are standard issue guns that an average soldier can hardly aim and fighter pilot planes which can cause the pilot to lose consciousness during certain tactical maneuvers.

Education. Recent theory and research in cognitive science, developmental psychology, and human intelligence are providing us with a better understanding of how individuals think and solve problems. This understanding can contribute much to the way teachers develop and deliver instruction in the classroom, particularly in terms of improving the reasoning, learning, and problem solving skills of students -- skills crucial in science and mathematics education. For example, we are beginning to unravel how children grasp arithmetic concepts and algebraic procedures. In addition, studies on reading have revealed the enormous impact of the family and home environment on children's level of attainment.

Further research is needed in these areas, along with the effect of computer instruction in the classroom. Given that most of our children's schooling by the year 2000 may take place via the computer, several

important questions emerge concerning the effects of this new medium on children's social interactions and spontaneous reading levels and family processes.

Research Training Needs

There has been almost exponential growth in the accumulation of basic theory and applications to major social problems -- growth which can be attributed in part to social and behavioral science research. The resolution of the problems facing us now and in the future may well rest on our ability to understand human thought and behavior. We ask that the trend of eroding Federal support for the social and behavioral sciences be reversed. Renewed commitment is urgently required in terms of federal support for training new researchers qualified to attack these problems.

It is important that steps be taken to achieve the NAS recommendations of 650 doctoral and 540 postdoctoral awards by 1987. This type of support has been instrumental in producing talented behavioral science researchers. For example, recent data for 1981-83 nonclinical doctorates in psychology indicate that individuals whose primary financial support in graduate school was a NSF, NIH, or NIMH traineeship/fellowship were more likely than graduates supported by other means to obtain academic employment upon graduation and thus be more actively involved in research.

In addition, consideration needs to be devoted to the development of new types of training programs which will more adequately prepare their graduates for attacking the complex research problems requiring attention. Innovative training opportunities in health psychology, psychology of aging, psychology and engineering, cognitive psychology, and the neurosciences need to be developed and expanded. Mechanisms for supporting interdisciplinary training through consortia of institutions and postdoctoral opportunities for receiving advanced training in other disciplines or methodologies (e.g., use of increasingly sophisticated scientific instrumentation) should be developed.

I thank you for this opportunity to testify.

TESTIMONY

COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. House of Representatives
Science Policy Task Force
Hearings on:
SCIENTISTS AND ENGINEERS: SUPPLY AND DEMAND

THE ENGINEERING JOB MARKET: SUPPLY, DEMAND, QUALITY, AND QUANTITY

by

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July 17, 1985

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THE ENGINEERING JOB MARKET: SUPPLY, DEMAND, QUALITY, AND QUANTITY

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ABSTRACT AND SUMMARY

The United States of America now faces some of the greatest challenges in its history. The country which once controlled a major portion of the world economy, and enjoyed the highest standard of living and quality of life is unable to compete in the world market and is now considered the largest debtor nation in the world.

Fields of new technology, created in the U.S., are controlled by excellence in foreign production. Markets once dominated by U.S. manufacturing enterprise are now major challenges as American industry finds competition difficult on new standards and market constraints.

As the U.S. loses controlling position in the world market, there is a direct impact on American jobs, taxable cash flow, trade deficits, federal budget deficits, and the status of the U.S. as a debtor nation.

Questions about the engineering and scientific capability of the United States are raised every time the nation faces a new crisis. The technical capability of the country is usually viewed from two perspectives: the number of engineers produced (the quantity issue), and the capability and productivity of the engineers produced (the quality issue). The engineering supply and demand question deals almost exclusively with the quantity issue. Unfortunately, the 'numbers game' is the one of most interest to the press and many public policymakers, since it can be expressed in simple terms, whereas, the quality issue is complex, pervasive, and requires a deep understanding of many factors. The quantity issue, in some respects, can be likened to the old adage that given a large enough room, sufficient supply of monkeys, and an adequate supply of typewriters, the monkeys would eventually produce the Declaration of Independence. Correspondingly, there are those who believe that the quantity of engineers produced by the nation is an indication of the American technical health. Unfortunately, engineering manpower has been looked upon as a commodity.

National policy decisions, made on the basis of the supply and demand issue, have had a profound impact on the quality of engineering in the country and may actually be part of the root cause of the crisis

America currently faces in productivity and industrial competitiveness.

Is there a shortage of engineers?

The nation has never had, does not now have, nor probably ever will have a shortage of engineers. The engineering job market demand is nearly impossible to predict because of many factors, for example:

> Federal expenditures heavily influence market demand;
>
> There is tremendous elasticity in the market because of the high variability in the utilization rate of engineering talent in different types of engineering practice;
>
> Advances in engineering technology (for example, computer aided design) directly and rapidly affect the productivity of the engineering element in a project;
>
> Many engineering graduates do not seek, and many experienced engineers abandon engineering practice careers;
>
> American engineering schools produce more engineers than the engineering job market requires.

The quality of engineering education is the issue of major concern. However, in order to evaluate quality, criteria must be established for the required skills which should be possessed by graduating engineers. Here lies the basis for raging debates over the past 30 years. What knowledge and understanding should engineers possess in order to meet professional needs, the needs of society, and the competent practice of engineering in a complex cost-conscious world sensitive to environmental protection?

There is no engineering education deficiency in the teaching of basic theory and the fundamentals of science, mathematics, and engineering science in engineering schools. What then is the crisis in the quality of engineering education? Some of the issues enumerated below illuminate the challenge:

> The present theoretical curriculum has very little relevance to the practice of engineering;
>
> Engineering education is nearly void of the teaching of engineering technology;
>
> Engineering programs provide an inadequate laboratory experience for relating basic theory and fundamentals to engineering systems and components;
>
> The curriculum contains little or nr exposure to communication arts, project management, financial and legal considerations, personnel policies and practices, manufacturing processes, innovation, and the interaction between

technology and environmental quality;

Engineering is taught on a subject basis whereas engineering is practiced on a project basis;

The curricula for engineering are unidisciplinary whereas engineering practice is multidisciplinary, and interdisciplinary.

Over 80% of American engineers enter engineering practice with a four-year bachelor's degree. Under current standards, this degree requires about 130 semester hours, comparable to other four-year degree programs in the arts, sciences, and humanities. The establishment of the credit-hour requirement had little if anything to do with the needs of the program, but rather was to keep the administration of engineering education competitive with other postsecondary education programs, raising the questions of what should entry level educational requirements for graduating engineers be, and do engineering programs have to be comparable to other postsecondary education degrees?

These questions have been debated extensively over the past 30 years. However, nearly all data indicate that it is not possible to adequately prepare engineers for industrial practice, in light of the crisis of productivity and competitiveness, if the undergraduate degree program must be held to 130 semester units. Additional courses and laboratories are needed to provide students with an understanding of the translation of basic fundamentals into practical solutions. The teaching of engineering must be accomplished by faculty who can infuse project and industrial practices into their programs. These quality needs run directly counter to well established policies in the engineering institutions.

Some people believe that the four-year degree need not go beyond basic engineering fundamentals, and that the graduate study programs can provide additional time for increased course and laboratory study. However, the current graduate degree approaches are constricting, not broadening, and practicing engineers have had little market or financial incentive to warrant their investment of time and money in the additional education.

The challenges which the nation faces in productivity and industrial competitiveness require whole new approaches in the education and training of engineers. Solutions will require many traumatic changes in national policies, institutional administration, commitment from industry, coordination within the technical community, and profound redirections in accreditation policies and procedures. To effect the crucial changes, the proactive political constituency must be developed which is a key element in the public policy process. Priority must be given to funding at state and federal levels, as the quality of engineering education will determine the future of the nation. The crisis may appear subtle to business and government policymakers preoccupied with the near-term solutions for political and financial reasons. However, if action is not taken, the nation should be prepared to see a steady decline in the standard of living, the quality of life, and in the leadership role which the U.S. has historically played in the world.

INTRODUCTION

Those who do not read history are doomed to relive it.

The issue of supply and demand of engineering manpower in the United States has been a matter of great debate over the past 30 years. Past attempts to predict the future needs of the market have been erroneous. The factors that affect the engineering job market are many and complex. The means for gathering data have influenced the result. Past attempts to predict the future engineering demand have all been worthless. There is a significant lead time in the development of an engineer. What are the ramifications of quantity and quality in the engineering supply and demand issue? How does the supply and demand question relate to the national challenges of productivity and industrial competitiveness?

Periodically, the nation goes through a rediscovery of the wheel. The issue of supply and demand of engineering talent in the nation has been one that has defied rational approach. What changes have occurred in the quality of engineering as a result of policies based upon perceived shortages in engineering manpower supply?

Every time the nation experiences an implied threat to its leadership in science and technology, it develops a concern for the number of engineers it produces. In the early 1950's the market for graduating engineers was not favorable. As the cold war heated up in Korea, the nation determined that its security required the development of intercontinental ballistic missiles and strategic bombers as nuclear weapons delivery systems. Suddenly, the engineering market changed, and there was a growing 'perceived' demand for engineering graduates. In 1958, the United States received a major jolt to its ego when the Russians launched a grapefruit-sized radio transmitter into low earth orbit, and the push was on again.

The Sputnik is an excellent case in point. From a national policy viewpoint, Sputnik was perceived as a manifestation of massive deficiencies in the U.S. technological capability. However, in actuality, nothing could be further from the truth. Sputnik was a demonstration of deficiencies in national technical policy and had nothing to do with the engineering and technological capability of the nation or the quantity or quality of the engineering talent.

The Sputnik crisis was created by national policies related to the U.S. commitment to the research program for the International Geophysical Year. Congress had determined that the U.S. would not enter space research programs using 'military-derived' hardware. To carry out this policy, Congress created NASA, a civilian-based agency, and began to develop the Vanguard rocket from its inception with 'clean' (non military) funding. The program experienced all of the normal challenges of new hardware development. The situation was

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compounded by the fact that there was a new federal agency at the helm.

Russia, not confused by the moral question of military versus civilian hardware, took existing military rocket systems, lashed them together to achieve the required 'impulse' to insert a small radio transmitter into low earth orbit, and scooped the world. The resultant 'beep, beep, beep' sent a major shock wave through the nation's policy process. History will record the impact of that Congressional decision for all future generations. However, Congress did not accept the responsibility for its actions. The rationale was that the United States was deficient in the education and training of engineering manpower and lacked technical capability.

Subdued in the historical record is the fact that the U.S. had a number of military systems that could have been used for greater theatrics and scientific accomplishments far exceeding the Russian event. The U.S. had Jupiter C, Redstone, Bomark, and other operational missile systems. The Atlas and Titan missile systems began development in 1955, and these rocket engines were considered by some to be the at the limits of technology in their size and thrust. By 1958, these 'advanced' rocket engines were well along in their development and were ultimately used in the U.S. space program (after an attitudinal change in Congress).

Shortly after the Sputnik crisis, the U.S. changed policy and began to use military-developed hardware for space research. The manned Mercury mission was accomplished using the Redstone rocket (developed in 1954). The Redstone was also used as the launch system for the Explorer I mission. U.S. launches taking place virtually months after the Russian 'accomplishment' indicated that the U.S. previously had the hardware to achieve more sophisticated objectives in space before the Russians, if an American national policy and commitment had wished to penetrate this frontier.

Sputnik had very little technical value, but the political implications were omnipotent. Tragically, the American science and technical policy machinery is most effectively fueled by political threats, real or perceived. Prior to Sputnik, there was no forcing function to justify the appropriation of funds for theatrics in space before the Russian show.

Two messages emerge from the 1950's experience: 1) changes in national technical policy (for such activities as space and defense) will have a direct and powerful impact on the engineering job market, and 2) misinterpretation of 'threats' can cause policy changes which actually exacerbate the engineering job market and the quality of engineering education.

NATIONAL POLICY ON ENGINEERING EDUCATION

The post Sputnik era in the U.S. saw major policy changes in the federal government's funding for engineering education. Unfortunately, many of the federal policies were predicated on a perceived deficiency in the U.S. technical capability. The assumption was that American engineering education programs lacked sufficient theory and basic fundamentals. To correct this perceived problem, the federal government poured massive funding into the nation's schools to strengthen basic research and the teaching of fundamentals. Graduate study support, targeted on increasing the number of advanced theoretical degrees, was also increased. The graduates of these programs were to become the teaching cadre for effecting new directions in engineering programs in the engineering institutions.

Federal expenditures for space and defense skyrocketed. This increase created a new market demand for engineers. In addition, government procurement practices, such as the Cost Plus Fixed Fee (CPFF) contract for research and development, strongly stimulated the defense and space contractors to aggressively compete for engineers to staff their potential teams. The universities were being asked to produce more engineers. To increase the number of graduates, the universities reduced the requirements for an undergraduate degree program to make engineering competitive with other four-year curricula. In general, a 'four-year' degree program, in most fields other than engineering, was considered to be 120 semester hours of study. Prior to that time, many of the country's engineering schools required upwards to 160 semester hours for the bachelor's degree in engineering.

Reflecting on the 1950's, what can be learned?

The procurement policies of the federal government are one of the most profound factors influencing the engineering job market (supply and demand) and the quality of engineering education. It is somewhat a case of the golden role, "he who has the gold makes the rule."

THE LESSONS OF THE 1960'S

Rapid changes in the quality and quantity of engineering talent in the late 1950's did not reach full impact until the mid 1960's. Interestingly, the space accomplishments of the early 1960's were made possible through the efforts of engineers trained before the Sputnik crisis. However, the changes effected as a result of the misinterpretation of that event are still in place and will affect engineering education for many years into the future.

The nation had less than one million practicing engineers in the 1950's with a production rate of about 40,000 graduates per year. With an engineering production lead time of from 6 to 8 years (considering secondary school guidance), the space accomplishments of the 1960's, including landing men on the moon, were accomplished by engineers, the majority of whom were trained before Sputnik! This fact is hardly an indication that the technical education of the nation was deficient in 1958!

PREDICTING THE ENGINEERING JOB MARKET - QUANTITY

During the 1960's, attempts were made to predict the engineering job market. The technique receiving the greatest recognition then and now used data which indirectly related to procurement practices. An advertising firm in New York correlated dollars spent for advertising for engineering talent in newspapers and technical journals to the engineering job market. This is the D.S and E. Index. 1960 was taken as the datum point with a D.S.and E. Index of 100. As the Index increased, supposedly the engineering job market indicated a shortage of engineers. As it decreased, the market was softening.

Other researchers challenged the use of advertising data to indicate the status of the engineering job market because of the different personnel advertising objectives of firms. High advertising expenditures may have no relationship to the actual market. A firm may use extensive advertising to search for one specialized engineer. Another may be developing potential contacts for new staff in anticipation of winning the competition for a federal contract. Still another firm may want to establish an optimistic image of growth to the venture capital market or create a feeling of well-being among existing staff that the company's future is bright. The Index may have some relative qualitative interest, but it cannot be used as an accurate indicator for future projections.

PUBLIC POLICY AND THE ENGINEERING SUPPLY AND DEMAND

The most important data for determining the engineering job market in the U.S. are from authorization and appropriation actions by Congress. 85% of all engineering service in the U.S. is procured through public expenditures directly or indirectly. Thus, the supply and demand issue is coupled to federal, state, and local public policies and procurements. When defense is a high priority in Congress, the engineering job market is good. When federal commitments are suddenly reduced, as they were in 1969, the engineering job market crashes.

In late 1968, the American Society for Engineering Education released a report called the 'Goals for Engineering Education' which resulted from a study funded by a $300,000 grant from the National Science Foundation. The study examined a number of challenges facing engineering education in the 1960's and beyond. One aspect dealt with the number of engineers required to meet future demands in the U.S. The report stated that the U.S. had a critical shortage of engineers and that if something were not done to correct that shortage, there would be a 'short fall' of over 300,000 engineers by the year 1975.

Less than a year after release of the report, the federal government cut its expenditures for research and development, and the engineering job market was immediately and severely jolted. The policy decision was assisted by a growing political constituency that was chanting, 'Why go to the moon when there are riots in the streets?' The U.S. Department of Labor established the 'Engineering Registry' to assist unemployed displaced aerospace engineers, scientists, and technicians in finding work. It also funded a job search and development program in 14 regional areas in the nation to assist engineers, cast out of the defense and aerospace industry, in finding jobs in the consumer product and service industries.

The U.S. Secretary of Labor lamented that the engineering unemployment situation was the most puzzling and perplexing that DOL had ever dealt with, since such highly trained and qualified individuals could not find jobs for the first time. The DOL was further confused, since many of the displaced engineers did not seek help through the DOL regional offices to locate new jobs. Many did not even seek unemployment pay.

The DOL was unable to determine, with any degree of accuracy, the actual engineering and scientific unemployment level. Terms such as 'over qualified' and 'aerobracero' were coined. The media carried horror stories about highly qualified engineers losing boats and homes and being forced to move from their communities to seek employment outside of the defense related industry. Estimates made by non-DOL researchers placed the engineering unemployment level at 100,000 with an additional 200,000 underemployed. Phd engineers were willing to take jobs as gas station attendants rather than be unemployed. This crisis had a rippling effect through the market as the 'overqualified' workers displaced those who would normally be filling entry level positions.

Non-defense employers were reluctant to hire ex-aerospace workers. Employers expressed the feeling that aerospace engineers were narrow in thinking, highly theoretical and lacking practical understanding of the competitive market; furthermore, these engineers were seen as not cost conscious, were over paid and underutilized, highly specialized, and likely to leave their new jobs and return to aerospace when government policy reversed in technical procurements. The consumer product and non-defense industry could not absorb the massive numbers of engineers displaced by the federal procurement cutbacks.

The California Legislature established a panel on 'Engineering, Scientific, and Technician Unemployment' under the Assembly Science and Technology Advisory Council. It was commissioned to examine the nature of the problem and what, if any, actions the state could take to alleviate the situation. The state could find no direct positive intervention.

The press-play given to engineering unemployment had a negative effect in the schools as students were counseled to carefully reexamine their career decisions if they were considering engineering.

OTHER FACTORS AFFECTION THE SUPPLY AND DEMAND ISSUE

Any analysis of supply and demand in the engineering job market must consider a number of highly relevant influencing factors, such as: the nature of the work, i.e., professional versus paraprofessional; engineering staff utilization rate; effect of new technology on engineering productivity; and differences among the various types of engineering work have major impacts on demand. In the latter case, one engineer in a consumer product industry may represent $10 million in cash flow, whereas one engineer working on an aerospace program, under a CPFF contract, conducting exploratory development, may represent $150 thousand in cash flow.

Periodically, technical and trade associations conduct surveys of their constituents to project future demand for engineers. These projections also have been found to be highly inaccurate. They are as valid as the assumptions upon which they are based. Some surveys are targeted on one or two disciplines of engineering, but policymakers erroneously interpret the data as being applicable to all disciplines of engineering. The utilization rate of responding firms is an extremely important parameter. Other factors such as offering salaries, cost of living in the geographical location of responding firms, anticipated growth rate of the firm, expectation of large government contracts, and other factors all bias survey data.

In the 1960's, in the 'era of engineering shortage', the federal government discovered that some contractors used their engineers to accomplish numerous tasks which paraprofessional or technician level personnel could have done. Some contractors were found to have a utilization rate for engineering talent of about 19%, i.e., 81% of the engineering staff's time was devoted to tasks that could have been performed by less well trained personnel. If the data were taken on face value, one would be led to believe that the contractor firms had five times the number of engineers required to conduct the engineering work. This view, of course, would be a highly questionable interpretation of the survey results, but utilization rate is an extremely important factor if job market projections are going to be attempted!

Engineering productivity has been ignored in nearly all job market analysis. For example, when the 'Keenan and Keenan Steam Tables' were produced over 40 years ago, most engineering computational work had to be done by hand using crude and slow mechanical calculating equipment. Thus, large numbers of engineers were required to conduct analysis which today can be accomplished in seconds with hand held calculators. The civil engineering associated with road construction in the 1950's required in-field surveying, hand calculations to define the road layout with the required cuts and fills, and the preparation of detail drawings that would be used by the construction firm. Now, most of the field survey information is obtained by aircraft photogrammetry techniques. These data are digitized and fed into a computer that has been programmed to select the best road layout for the design requirements. Layout and detail drawings are created by an automatic printer, and the computer prints out all of the specifications for construction of the road. Manpower projections ignoring changing engineering technology will be worthless.

Computer aided design (CAD), computer aided engineering (CAE), computer aided manufacturing (CAM), and computer integrated manufacturing (CIM) are all examples of new systems having a profound impact on the numbers of engineers required to perform very complex tasks.

THE JOB MARKET OF THE 1970'S

The Arab oil embargo of 1973 created a new national threat, and the country was again questioning its technical capability. One California legislator immediately attacked the University of California for not alerting the policymakers to the impending crisis. What was going on in research to provide energy self sufficiency? What new programs are needed to protect the nation from decisions by OPEC? Should the U.S. have an energy czar? What alternative fuels and power options can decouple the nation from foreign energy decisions? In true form, reacting to the threat, the Federal Energy Administration was formed and later the Department of Energy. Many states formed their own energy administrations with widely varying agenda. Engineering schools saw declining enrollments in the aerospace engineering curriculum developed in the 1960's and sought to foster new programs in energy. Some even proposed new degree programs in energy.

The Energy crisis did not create the same level of federal commitment as did the defense and space challenge of the 1950's and 60's. However, the 1970's saw the continued dismantling of some of the major elements of the space program. After successfully landing men on the moon and returning them safely to earth, the man-moon program was terminated. All remaining moon mission hardware was scrapped or salvaged, contracts were completed, technical teams were disassembled, and all manufacturing, test, and launch facilities associated with the man-moon mission program were destroyed as a requirement for contract close-out.

THE CRISIS IN ENGINEERING FOR THE '80'S AND BEYOND

The nation is experiencing the worst international deficit in trade balance in history. There is concern for increased productivity, quality control, product development, entrepreneurships, intrepreneurship, industrial development, and industrial competitiveness. The U.S. must learn to compete effectively in the world market. American industry must develop the means for attracting the American consumer back to domestic produced products. American schools must be concerned with the quality of their graduates and never sacrifice that objective to increase numbers of graduates. The time for rhetoric is over, and action must be taken on all fronts. There are no simple solutions to America's current crisis, and policymakers must be willing to make difficult decisions in the face of established vested interests.

The quantity issue can be resolved quite easily. In a free economy, there is one way to determine a shortage of a anything; it is the price the market is willing to pay. A plot of starting and median salaries for engineering talent over the period of 1960 to the present, adjusting the salary numerical values by the consumer price

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index, is quite revealing. The data indicate an increase in the value of an engineering manhour from 1960 to 1967. After 1967 and through to the present, there has been a steady decrease in the actual remuneration level for engineering services. For the most part, since 1967, the value of engineering service has not increased even at the rate of inflation.

The amount of disposible income that an engineer has after meeting all fixed obligations can be correlated to the quality of life. In the 1950's, less than 25% of an engineer's gross salary represented a house payment. In 1985, in many of the hot-beds of engineering employment, the house payment exceeds the gross income for the engineer. Thus the 'American dream' of home ownership is denied most young engineers unless there are two working members of the family and the total income of one is dedicated to house payments.

Over the past two years, the data from the nation's college placement offices indicate that the actual (not considering inflation) starting salaries for some disciplines of engineering have declined. Thus, the job market, as interpreted through normal supply and demand coefficients, says that there is no shortage of the 'commodity' called engineers.

What then is the problem?

PRODUCTIVITY AND INTERNATIONAL COMPETITIVENESS

The U.S. still invests heavily in basic research and product development. Many of the breakthroughs in electronics, biogenics, and other areas are the result of the nation's public and private research efforts in educational institutions, industrial firms, and public research facilities. The challenge the nation faces is the translation of research discoveries into new high quality products at competitive prices; this is one area in which the competitive crisis exists. Cost of labor, automation, new systems, management approaches, labor/management relations, labor laws, and other factors contribute to this challenge. Engineering is a principal element of the challenge; it is at the heart of the innovation process.

An old midwestern farm phrase is quite apropos. "A silk purse cannot be made out of a sow's ear." The quality issue must be directed to the capability of American engineering to deal with competitiveness. The current challenge facing the quality of engineering education is not a deficiency in theory and fundamentals. Current engineering programs are steeped in these areas. Students also receive an excellent exposure to the field of computing science. The challenge is that the current engineering curricula do not prepare engineers for the realities of industrial practice in the crisis of competitiveness.

In some respects, the educational system can be compared to a major manufacturer subcontracting the production of components or subassemblies. In this analog, the manufacturer is the industry hiring engineers. The engineering schools are the subcontractors.

The engineering schools (subcontractor) determine the design and function of the engineer (the component to be supplied), and the manufacturer accepts the product as delivered and attempts to redesign or modify it to meet the needs of industry. What manufacturer would use this approach in normal business? What manufacturer would issue an open purchase order to a supplier to produce "something" and then completely remanufacture the supplied component after receipt?

The challenge facing the nation in the preparation of engineering talent lies in resolving the wide difference of opinion concerning the skills which the engineer should possess upon graduation. The educational process assumes that every engineering student is a candidate for graduate work in a theoretical or fundamental field. The goal has not been to produce highly capable and productive individuals for industrial enterprise. The engineering curriculum is unidisciplinary in nature, taught on a subject basis, and has a "micro" orientation; whereas engineering practice is interdisciplinary and multidisciplinary, practiced on a project basis, and has a "macro" orientation. Here lies the problem!

PERCEPTION OF THE QUALITY ISSUE

A cursory survey of industrial firms would likely produce a general statement that new engineering graduates are very bright, and have a good background in theory and fundamentals. "The best we have ever had--!"

A more in-depth exploration with most industrial firms brings forth a new set of data. "Our engineers are slow readers, cannot write, have little command of communication arts, have no knowledge of industrial management, do not know how to translate theory into design, have no knowledge of manufacturing practices, would rather play with the computer than go to the shops and work with the technicians and machinists, know nothing about marketing, don't understand problems associated with labor management law and collective bargaining, and are insensitive to cost," lament many industrial managers.

Engineering graduates must have a higher than average I.Q. or they would not make it through the rigors of an engineering program. However, a high I.Q. does not automatically guarantee success and productivity in the industrial environment. Current engineering curricula need to be strengthened to include courses and laboratories crucial to increasing engineering capability in industrial practice. In some respects, the term "engineering degree" today would more accurately be called an "engineering science degree."

THE SOLUTION

The challenge of international competition dictates the requirement for a a new commitment to excellence in technical education. It is recommended that:

The "numbers game" should be abolished permanently.

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The engineering schools, with strong guidance and support from industry and government, should move quickly in restructuring engineering curricula preparing engineers to address the challenges of productivity and competition.

Programs, such as the Engineering Research Centers sponsored by the National Science Foundation, should be expanded with the prime purpose of stimulating interdisciplinary engineering education.

Universities should recognize industrial research and experience as equivalent to academic credentials and basic research in providing tenure-track opportunities to non-Phd faculty.

Accreditation requirements should be modified to provide the stimulus for increasing and engineering understanding of innovation and entrepreneurship in world competition.

States should recognize that the majority of the challenge of competition can and should be addressed at state level and then develop policies, backed with appropriate funding, to effect change in publicly supported institutions.

Support mechanisms must be developed to permit private postsecondary educational institutions to provide broad flexibility in their programs.

Paramount in all of these recommendations is the assumption of responsibility for effecting meaningful change. Presently, no single organization has the responsibility, authority, or commitment to provide the forcing function crucial to implementation. The initiative must come from an awakened and proactive private sector. The stimulus for profound change can come from the public sector. The educational sector is a service industry whose mission should be an accurate and rapid response to a critical need.

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THE ENGINEERING JOB MARKET:
SUPPLY, DEMAND, QUALITY, AND QUANTITY

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He has written and lectured on many topics related to engineering and technology including: engineering education, the engineering job market, invention, innovation, intellectual property rights, product development, and technical public policy. He has consulted for legislative bodies and has provided expert testimony in legislative hearings.

THE ROLE OF UNDEGRADUATE INSTITUTIONS IN SCIENCE, MATH, AND ENGINEERING EDUCATION

PRESENTED TO THE U.S. HOUSE OF REPRESENTATIVES
SCIENCE POLICY TASK FORCE

ON BEHALF OF

AMERICAN ASSOCIATION OF STATE COLLEGES AND UNIVERSITIES

Introduction

There is no question as to the substantial role undergraduate institutions play in educationg our nation. Over half the U.S. population enters a postsecondary degree program, many choosing to attend a four-year institution. But what is even greater, is the role that undergraduate institutions play in maintaining our nation's talent pool in the areas of mathematics, engineering and sciences. Undergraduate institutions provided more baccalaureate degrees for our nation's scientists, engineers and mathemtaticians than many major research institutions. A recent study by the National Society of Professional Engineers shows that approximately 50 percent of the baccalaureate engineering degrees are granted at undergraduated institutions. Since engineers tend to terminate their degree at the BA level, undergraduate institutions are providing the primary training programs for approximately 50 percent of the engineering profession.

Beyond their contribution to the engineering profession, undergaduate institutions educate a substantial number of the students who continue on in Ph.D. programs across the science disciplines at research institutions. For those students who choose to enter fields other than math, science or engineering, the baccalaureate degree is their last formal exposure to math and science concepts. Finally, it must be noted that undergraduate institutions educate the majority of teachers in our nation, including those who will enter pre-college math and science classrooms.

Thus, no consideration of federal science policy could be considered complete without a discussion of undergraduat institutions and the unique problems that they face in providing quality education, particularly in the areas of mathematics, engineering and the sciences.*

Underlying an undergraduate institution's commitment to quality education is the institutions responsibility to maintain and/or improve the basic factors that comprise the baccalaureate science degree: quality faculty, prepared students, state-of-the-art equipment, and an up-to-date curriculum. Each of these factors will be addressed individually.

*Hereafter, the areas of mathematics, engineering and the sciences will be referred to as "science."

Faculty

Undergraduate institutions are primarily teaching institutions. As a result, faculty teaching loads often range from 12 to 15 contact hours a week as opposed to the three to nine contact hours carried by faculty at research institutions. Such a heavy teaching load makes it especially challenging for a faculty member to stay abreast of new developments in his/her field and even more difficult to pursue one's own research interests. Science faculty members at undergraduate institutions often feel alone and isolated from their field as well as feel an absence of 'criticial mass' to encourage and support their achievements both in teaching and in research.

Participation by faculty members at undergraduate institutions in sponsored research programs is often limited. Slower rates of publication can affect the review of a proposal. Equipment, supplies, and administrative support is limited. And, undergraduate faculty do not have access to a supply of skilled graduate assistants. In combination, these conditions make it difficult for undergraduate faculty members to compete with their colleagues at research institutions. The result is a limited amount of research being done on undergraduate campuses in spite of the many talented faculty members who are interested in participating in sponsored research programs.

In addition to affecting the quality of undergraduate faculty members, the lack of research opportunities for researchers at an undergraduate campus contributes to another problem that is not unique to undergraduate institutions; the short supply of faculty. This shortage is especially chronic in the area of engineering. In 1983, the American Society for Engineering Education found that the number of unfilled positions as reported by deans of engineering ranged from 1,567 percent to 6,700 percent. This shortage comes at a time when enrollments in engineering courses have increased substantially. Undergaduate institutions are particularly affected by these conditions as these institutions are unable to utilize graduate teaching assistants to reduce the load of full-time faculty members. In combination, the lack of research opportunities, heavy class loads, and low salaries have led to a decline in the number of students continuing on as faculty members. This is in addition to the continuing need to replace retiring faculty.

The National Science Foundation has recognized the importance of research at undergraduate institutions and its direct link to faculty satisfaction and the education of future talent through the development of a cross-directorate program that allows undergraduate institutions to compete for support through a separate funding mechanism. In FY 1985 , the Research at Undergraduate Institutions Program (RUI) will fund $7.6 million in research programs at institutions that grant fewer than 20 Ph.D.s in the sciences every two years; in departments that do not offer the Ph.D proposals are reviewed by the regular review panels; however, reviewers are given additional instructions. RUI program objectives include the support of high quality research as a means of preparing students for careers in

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science and to contribute to a stronger research environment at undergraduate institutions. Recently, a review team made up of undergraduate researchers gave the RUI program a favorable assessment in meeting these objectives in its first year of operation.

Other mission agencies should be encouraged to capitalize on the resource of talented researchers at undergraduate institutions. Clearly, the return on program dollars is increased when beyond producing a research project, the undergraduate researcher is aiding his/her institution and students by expanding, or in some instances, creating a research environment on an undergraduate campus.

Equipment

In addition to affecting the quality of faculty at undergraduate institutions, the lack of a research environment on a campus impacts the supply of both research and instructional equipment. Without the assistance of some sponsored research projects, few institutions have access to the kind of capital that permits the acquisition and maintenance of basis research equipment. The 10 year life-span of a piece of laboratory equipment is quickly being shortened by advances in new technologies and by the rapidity at which these changes are taking place.

Instructional equipment, key in the preparation of future researchers, is often limited to the basics and thus fails to ready students for the state-of-the-art equipment they will encounter as they further their careers both in industry and in graduate school.

Support for the purchase of research and instructional equipment has traditionally come from both federal and institutional resources, or in the case of publicly supported institutions, included in state appropriations. Industry has also supported the instrumentation of institutions through the donation of equipment. Yet in recent years, support for undergraduate institutions has declined at a rate comparable to that of the research institutions.

Federal program support to assist undergraduate in the acquisition of instructional instrumentation is limited to the College Science and Instrumentation program at the National Science Foundation ($5 million). And a low rate of participation in sponsored research projects means that little research equipment is acquired indirectly, as part of sponsored research projects.

Industry, also affected by the high cost of state-of-the-art research equipment and the speed of developing technologies, has been limited in its ability to provide continued support to institutions at the two-year, four-year and research levels. Even with the median age of institutional equipment twice that of industry instrumentation, the value of an out-dated donation is limited.

In recent years, several reports have documented the state facilities at major research institutions. We have also seen a series of discussions and publications that suggest how the federal government can assist in addressing both the equipment deficit and the "brick and motar" problem.

of the recommendations call for federal assistance in the form of R & D tax incentives, direct matching grant program and modifications in indirect cost recovery procedures. Together, these efforts could restore our nation's academic research infrastructure.

It is important that in addressing the needs of all the institutions, consideration be given to the unique problems of each academic sector. Care should also be given to insure that all institutions are able to benefit from any program for revitalization. H.R. 2823 provides one example of how this can be accomplished. By directing a certain percentage of the program towards these institutions who do not normally participate in federal sponsored research programs, the level and type of competition is altered and undergraduate institutions are able to participate in such programs.

Undergraduate institutions would also benefit greatly from the revitalization of major research institutions if these programs were designed to encourage some sharing of facilities with area institutions. Faculty and even students from undergraduate institutions could be included on some research projects. Researchers from major facilities could be released to spend some time on an undergraduate campus to either lecture or perhaps even teach. The involvement of non-research institutions in research projects either on or off the research site assists in stimulating faculty, providing faculty with some research opportunities and thus serves as an excellent means of assuring undergraduate faculty currency.

The opportunity for undergraduate student exposure to a major research facility and its researchers could stimulate the positive perception of research as a possible career choice. It could also provide some "hands-on" experience for the student. Overall, the incorporation of undergraduate institutions into research proposals maximizes the use of limited dollars by addressing problems above and beyond facility revitilization.

Curriculum

Recently, concern has been expressed for the decline in quality of pre-college math and science education and the effect of this decline on student preparedness for college science, math and engineering programs. These concerns have been documented in several places such as the report of the National Commission on Excellence in Education (1983) and a 1984 National Science Board report. In the field of engineering, this concern is somewhat negated by the subtantial increases in enrollment and reports from industry that the quality of engineering graduates is higher than ever. Yet, the long term impact of a decline in student preparedness will affect all fields as institutions will be forced to devote an increasing portion of a student's educational experience to remedial education. This applies to the degree programs of both science and non-science majors.

Remedial education is costly, especially for institutions with limited faculty and resources. Thus, it is in the interest of all educators, as well as the federal government, to support efforts to improve pre-college science and mathematics instruction. Undergraduate institutions can play a special role in this effort as they are a primary educator of pre-college math and science instructors. Undergraduate institutions have also participated in grant programs that support pre-college curriculum development, school/college partnerships, and teacher training institutes.

Beyond assuring adequate student preparedness, institutions must design and maintain quality programs. At the undergraduate level, institutions are challenged to design a curriculum that not only provides an adequate education in a particular field, but that also gives students some written and oral communication skills, along with some stimulus to continue learning. Also assumed as an essential element in any science curriculum is the opportunity for "hands-on" experience. With the limited access undergraduate institutions have to both instructional and research equipment, students often leave the four-year campus with a baccalaureate degree that does not include much exposure to the equipment of his/her field.

In fields where constant advancement is the norm, curriculum such as the sciences and engineering must be frequently updated. This is often difficult to accomplish when faculty are not able to keep up with the field.

Finally, curriculum development must incorporate the use of new technologies in teaching methods. For example, courses should be designed to capitalize on the resources of computers in learning.

The challenge of designing an undergraduate curriculum should be met with the help of both industry and the professional sciences, along with the support of the federal government. The development of model programs could set a standard from which all institutions could work.

Students

The factors of faculty, facilities, and curriculum have their ultimate impact on the science, math, and engineering student. While the brigthest students are able to excell beyond the limits of their instructors, the average student is limited to the education provided in the classroom.

The lack of exposure to equipment, especially state-of-the-art equipment, restricts the depth of education to that which can be extracted from a text or lecture. This increases training costs to a potential employer, thus reducing the employability of a graduate. With limited research activity on undergraduate campues, students are not exposed to role models that could stimulate their interests in pursuing careers in research. Finally, the quality of an undergraduate curriculum is reflected in a student's ability to succeed in a career either in industry or in graduate school as the undergraduate degree is designed to serve as the basis from which the professional develops.

Consideration must also be given to the changing composition of the student body and the new demands that these alterations will place on the educational system. While the representation of both women and minorities in science classrooms is far from that of the general population, these enrollments have been increasing. With these students come an additional set of problems that are based in social, economic, and educational origins. This is especially true of undergraduate institutions as they educate the majority of first generation students. A substantial portion of minority students are also first generation college sudents. Once enrolled in science programs, the attrition rate of minority students is disproportionately higher than that of traditional science students.

Programs designed to increase minority participation in science programs, as well as retain minority students once enrolled, should be expanded and supported by insttitutions, the professional societies, and the federal government all in an effort to promote the partcipation of these students in the sciences. As a growing percentage of our total population, it is essential that these human resources are tapped and trained.

Conclusion

Overall, undergraduate instituitons support both industry and graduate science programs with a steady supply of educated manpower. These institutions attempt to instill in their graduates the basic concepts of the field, as well as the ability to adapt quickly to new technologies: all on very limited resources.

Recommendations from the President's Commission on Industrial Competitiveness, a group composed primarily of industrial leaders who focus on the actions the Nation must take to to compete internationally, stress the importance of the protecting our technical and scientific knowledge base, as well as our talent base. The Commission emphasized the importance of our academic system in supporting that knowledge base.

As the role of the federal government in science policy is discussed, it is essential that all sectors of the academic support system are acknowledged for the contributions that they make to our talent and knowledge base. The National Science Foundation has recognized the role that undergraduate institutions play in supporting the sciences and has developed programs such as the Research at Undergraduate Institutions program, the Research Opportunity Awards, and the College Science Instrumentation program to aid these institutions. Other agencies should be encouraged to tap this resource and develop programs to support these institutions as well.

The impact that undergraduate institutions have on the nation's scientific and technical knowledge and talent base demands that these institutions be recognized and supported in federal science policies.

APPENDIX 7

RECEIVED
JUN 27 1985
COMMITTEE ON SCIENCE
AND TECHNOLOGY

THOMAS S. SHEVLIN
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Reply to:
P.O. Box 128
Athens, OH 45701

June 24, 1985

Rep. Don Fuqua
Chairman
The House Science & Technology Committee
U.S. House of Representatives
Suite 2321 Rayburn House Office Bldg.
Washington, D.C. 20515

Dear Rep. Fuqua:

On September 17, 1984, I wrote a lengthy letter (copy enclosed) setting forth my concerns for engineering and the hope that engineering would receive proper attention from your Committee on Science and Technology. You were kind enough to reply, noting that our style was, in part, pressured into existence by our universities. I certainly agree, and attempted to say as much in my letter by saying that Federal money was accepted in our schools and an industry relationship was thenceforth unnecessary. As this style progressed, it was encouraged, even demanded, by the academic community. So, I believe, we have a common understanding.

In more recent months, it has been noted by various groups that we in the U.S. employ about 1/4 the number of engineers per capita as do Japan and Germany. This, of course, leads to fewer engineers in management and (in my opinion) tends to explain some of those atrocious management decisions now being noted; e.g. Harold Geneen's track record, reviewed in the Wall Street Journal, and the Abernathy and Hays article in Harvard Business Review, "Managing our Way into Economic Decline."

While I agree that both management and academics have made many specific obvious errors, I simultaneously suggest that the absence of true engineers, trained by engineers, has a significant bearing on our national economy and our closely related international trade.

Your Committee is well into its first year; how are you doing?

Sincerely,

Thomas S. Shevlin

Thomas S. Shevlin, P.E.

Enclosed: a/s

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Reply to:
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September 17, 1984

Rep. Don Fuqua
Chairman
The House Science & Technology Committee
U.S. House of Representatives
Washington, D.C. 20036

Dear Rep. Fuqua:

A small Washington newsletter which I received indicated that you would be the chairman of a committee to conduct a two-year in-depth study of the policies governing the federal support for basic and applied research. According to the newsletter, you expressed a certain satisfaction with the American science contribution over the last 35 years, but also expressed a concern for the future.

By way of introducing myself, I am an engineer, trained before WWII, and I am, therefore, at virtually the end of my career. This career has been spent approximately half in industry and approximately half in two major universities. Two years ago, there was the high honor (for me) of serving as the Stocker Professor of Mechanical Engineering at Ohio University, although my training had been largely in the area of material studies (Ceramics, Metallurgy, and Polymer Chemistry). My baccalaureate was received in 1942, and advanced training was gained during the period of 1946 to 1954, while employed on various government research contracts and while supervising other government research at the Ohio State University. I was sufficiently fortunate as to be able to be so employed, to engage in advanced studies and to conduct a substantial amount of consulting for industry and government at that time. It was most fortunate to have had these opportunities in the early days of my career because they provide a basis for subsequent judgemental assessments.

After Ohio State University, a tour followed at the University of Washington where I was instrumental in helping that institution to secure the NASA research contract which I headed and which has continued at the University of Washington for the past 20 years. I was also instrumental in starting a doctoral program at the University of Washington in Ceramic Engineering.

After the University of Washington, there were 20 years at the 3M Company, spent in various research, supervisory, and entrepreneurial activities. About 12 patents were assigned and at least one new business, creating some 50 jobs, was started. Perhaps, this is sufficient to indicate a fairly broad experience. My only purpose in these brief comments is to try, like most of us, to leave things a little better than I found them by offering a few observations which have been rather carefully considered and reviewed over a lifetime, and which might be of some small value to you and your committee.

As you must know, WWII was followed by a period extending substantially through the present, during which the Federal Government made very heavily funded contracts with science and engineering departments of universities throughout the land. Ostensibly, the purpose of many of these contracts and much of the style of operation was to bring closer together in time the discovery of new knowledge and its application in industry and often in that particular industry segment relating to the military. While the intent may have been good, the effect was to underwrite the cost of a divorce between educational institutions and American industry, the result being that industry stood back and said, you have no respect for our needs for proprietory information, patents, etc. and the university said, you have no respect for our mission to extend and purvey knowledge. This condition could be sustained because the university no longer needed money from industry. The condition was quite different before WWII, particularly in engineering departments, where such funding, as there was, came from industry to help support undergraduate and graduate studies of a particular type. In this period, continuing substantially to the present, there was a variety of attitudes about the responsibility for the expenditure of public money and the benefits accruing from these expenditures with respect to who the beneficiaries should be, etc., etc., etc.

Many government agencies maintained that they had no interest in the application of the new knowledge they were seeking to develop through the funds they were providing. Perhaps, this was simply a matter of remaining above suspicion of using public money for the benefit of the private sector. For whatever reason, this attitude was far reaching. On one occasion, when a government agency demanded that my research group supply 12 samples of our best effort to develop a new material at the end of the contractual period, my associates became enraged at this novel and "unreasonable" requirement. On the industry side, there was a position that they simply could not do business with the universities because they refused to assure confidentiality and patent rights while insisting upon the right of publication. What all this leads up to is that the character of engineering underwent a substantial change in the post-War period in the U.S.; in other countries, it did not.

This change is one in which engineering departments began to engage in more and more nearly scientific studies and tended to abandon many

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of the good practices which had prevailed before WWII. For example, before WWII, many universities would not hire engineering faculty lacking at least 5 years industrial experience. No suggestion of such qualification exists today. In the post war period, as manpower became increasingly necessary to staff well-funded government research contracts, graduates of a given institution would remain at that institution for graduate study and sometimes for faculty employment on completion of their doctoral requirements. Before WWII, graduate study was always pursued at a second school. The result of all this is fairly obvious. We now have engineering faculty who have only scientific training, no industrial experience, no economic or societal responsibility experience, and are said to be engineers, capable of training engineers.

Perhaps, it is timely to say a few words about the essence of engineering. Engineering should be concerned with getting a job done, with doing it efficiently, with doing it economically, with doing it in a timely way, with doing it with high regard for public responsibility and, perhaps, in doing it because there is a great satisfaction in simply building well a road, an engine, a brick, a skyscraper, a tire, and many, many other things which satisfy public and private needs. Engineering today no longer emphasizes the simple matter of getting the job done. It no longer emphasizes doing it economically. It no longer emphasizes the matter of public responsibility. You may well ask then how our engineering departments and curricula are qualified by visiting examiners who are there to maintain standards. The answer is very simple. The economics are taught in the Economics Department; financial management is taught in the Business School; and Political Science is taught in the Political Science Department. What's wrong with this? What's wrong is that when the student comes back to his major engineering department, there are no faculty people who can relate economic values to his studies. There is no one who can tell him anything of the political forces behind the fact that the bridge fell down. There is no one to tell him that he has a professional public responsibility to do things well. There is no one to tell him about the day they had to double production with no additional equipment. There is no one to teach first-hand case histories with the conviction of a participant. The student no longer receives engineering training. He is trained as a scientist and called an engineer.

In the U.S. Post War Period, there have been no Federal monies designated to study productivity, inventory control, manufacturing methods, quality control, process development, or any engineering studies of any kind. Obviously, I think, this is important or I would not be writing you this lenghty letter. I believe it is at the root of our loss of our international markets. I believe it is at the root of our decline from the position of being the greatest industrial nation on earth.

Perhaps, there are a hundred, perhaps two hundred people who have thought somewhat as I have, who are still alive, who might be of some service to your committee because they have seen things when they were quite different from what they are today, and in some ways, I believe, quite a lot better.

It should be remembered that technology is simply a "how to do it", and that technology is best which is most economical of materials and resources, that technology is best which requires the least expenditure of direct human manpower or brainpower. A hay bailer was a kind of robot, you know.

We are not being out-classed in the world markets because of cultural differences, except, that some people work harder, manage better, and avoid the unconcionable conflicts between management and labor that we have in this country.

What do I really mean by the lack of engineering training and its consequences in the United States? Let me give you a few examples. The Ben Fairless Works of the United States Steel Company was obsolete the day it opened its doors. Anybody who had any knowledge, however remote, of the steel industry knew that the basic-oxygen-vessel was the way of the future and the long open hearth campaigns were dead. How about small cars and General Motors? It took an act of Congress to force G.M. to build small cars because they knew what the public wanted despite the fact that what the public wanted was demonstrated by their purchase of German and Japanese automobiles of small to medium size. These are monumental management errors, and they were not made by engineers who were trained by other engineers. They were made by people who studied finance and administrative techniques, and had a certain methodology orientation and little experience on which to base sound judgement. Compound these a thousand times, and it is easy to see how the absence of genuine engineering training in our society has damaged our industrial position vis-a-vis the rest of the world. Sound engineering is not everything, but engineering being, nominally, the largest profession in the world, it is certainly something significant.

Cordially yours,

Thomas S. Shevlin

Thomas S. Shevlin, P.E.

P.S. Enclosed are Secretary Richard de Lauer's remarks quoted in the same newsletter and my comments. There seems to be a fairly typical emphasis on science.

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The Word From Washington

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VOLUME XIII NUMBER 33 AUGUST 24, 1984

DEFENSE VIEWPOINT Richard deLauer, Under Secretary of Defense for Research and Engineering, recently sent a letter to President Reagan calling for a Presidential initiative to restore the United States' scientific and technological leadership position in the world. The letter, which deLauer said he wrote with Defense Secretary Weinberger's encouragement, said in part:

> "In 1957 when the Soviet Union launched Sputnik,① the Eisenhower Administration initiated an intensive campaign to regain our world leadership position in science and technology. For about a decade following that event, the United States built② a scientific and technological base second to none by supporting quality education and research in the sciences and engineering which paved the way for today's advances in medicine, agriculture, energy, electronics, and aerospace③ — advances undreamed of in 1957. A key ingredient in those years was a vision of what could be achieved by educators, industry and government working together to strengthen science and engineering research and education at all levels.

> "Since the mid-70's, however, we have allowed our technological lead④ to erode and our support for education and research to decline. Our research and teaching institutions already are having serious difficulties producing the quality scientists and engineers⑤ needed to regain the technological lead so essential to our future security and economic well-being.

> "Recent studies now show that as the economy improves and production increases, the United States will experience serious shortages of certain types of scientists, engineers and other trained support personnel in fields⑥ vital to both the nation's health and its defense. Shortfalls in some specialty areas are already slowing our recovery, and will affect such pioneering efforts as DoD's strategic defense initiative and NASA's space station, as well as our continuing advances in fields⑦ such as microelectronics and biotechnology.

> "Education at all levels is at present unprepared to meet this challenge. The deteriorated state of high school education in science and mathematics has recently been well documented while similar studies of higher education have revealed major deficiencies in engineering faculty,⑧ obsolete laboratory facilities and equipment, and large declines in the numbers of American citizens pursuing advanced degrees.⑨ We can no longer rely on our educational institutions alone to provide the levels of science and engineering education required to maintain leadership in an increasingly technological world. A renewal of our traditional collaboration among schools, universities and high technology workplaces is essential if we are to recover lost ground and maintain our technological edge."

COMMENTS:

(1) Sputnik was an engineering achievement. We learned the wrong lesson, and over-emphasized science.

(2) Quality education? The President's study group said its deterioration was so serious that if caused by a foreign country, we would call it sabotage.

(3) The vision was a pre-war reality in the U.S. and a post war reality abroad.

(4) Scientific lead; yes. Technological lead; never to doubtful.

(5) Quality engineers? Of course, we are not producing quality engineers; we are not producing any engineers.

(6) How about such economically, practical fields as high speed surface transportation network for distances of 100 to 500 miles? We have the right-of-ways.

(7) Why not say what we mean - no true engineering faculty.

(8) Advanced degrees? Ph D's? What about the all-but-forgotten P.E. (professional engineer) Degree for engineers based upon experience, standards of performance, and peer review. Many engineering schools awarded them through about 1949, whereafter, they were replaced by the PhD, and even later, the MBA became a sort of regrettable replacement.

(9) In general, an acceptable sentence, but why the limitation to "high technology workplaces"?

AMERICAN NUCLEAR SOCIETY
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[illegible]

August 5, 1985

The Honorable Don Fuqua
House Committee on Science
And Technology
Washington, D.C. 20515

Dear Congressman Fuqua:

On behalf of the American Nuclear Society, I am pleased to respond to the invitation to submit comments for the hearings of the Task Force on Science Policy. One of our principal concerns relates to the continual and dramatic decrease in the support of nuclear engineering and applied nuclear science education. I believe these trends are the result of two incorrect perceptions on the part of both the general public and the federal agencies. The first misconception is that with the decline in plant orders and cancellation of nuclear plants following the 1973 oil embargo, nuclear energy has no significant role to play in the national energy mix and is a "dead end" technology. However, a power source that is providing nearly 15% of the national electricity generation, and in some areas up to 60% is of critical significance. With an additional 30 to 40 nuclear plants coming on-line within the next few years, the need for educated and qualified personnel to staff these plants remains high. Indeed, results of studies conducted by the Oak Ridge National Laboratory (ORAU--231) indicate that there very likely will be significant shortfalls of qualified graduates over the next 15 years.

Secondly, there appears to be a feeling that the only nuclear engineering opportunities are with commercial nuclear utilities. While many of the graduates do accept employment with these organizations, degree holders in nuclear engineering and applied nuclear science also make significant contributions in a wide variety of technical areas including biology and medicine, industrial applications, national defense, space technology, advance nuclear systems, and basic research. I suggest that if the capability of our colleges and universities to provide nuclear engineering and applied nuclear science education is allowed to languish, this would constitute a serious loss in the scientific and technical resources of our nation.

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COMMITTEE ON SCIENCE
AND TECHNOLOGY

The American Nuclear Society supports the statement by Professor Glenn Knoll of the Nuclear Engineering Department Heads Organization (NEDHO) that continued and vigorous support is warranted for the nuclear energy and applied nuclear science departments in our educational institutions. ANS enthusiastically endorses the recent Department of Energy initiative, Notice of Program Interest NE-85-001, which has allotted approximately $4 million for direct faculty research support at universities. We, however, concur with NEDHO that an adequate funding level of about $12 million per year is needed. We further agree with the need to expand the DOE fellowship program so that talented and capable students can pursue advanced graduate research and degrees.

Finally, I would like to call your attention to the difficulties experienced by university research reactors in maintaining their level of equipment and services. While it is commonly assumed that research reactors are linked only with nuclear engineering departments, these facilities in fact provide a valuable resource for the research of activities a variety of basic and applied academic departments. A research reactor may typically be utilized from by departments ranging from physics, chemistry, biology, and the associated physical and natural sciences to engineering, agriculture, medicine and a variety of other disciplines. ANS encourages the Task Force on Science Policy to recognize and focus on the unique role played by university research reactors in the scientific capability of our universities.

I want to express my appreciation to the Task Force for considering these remarks. Should further information or testimony be useful, the American Nuclear Society would be pleased to respond.

Sincerely,

E. Linn Draper, Jr.

E. Linn Draper, Jr.
President, American Nuclear Society

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
RESEARCH LABORATORY OF ELECTRONICS
CAMBRIDGE, MASS. 02139

Room 26-237
(617) 253-6811

August 8, 1985

Dr. John D. Holmfeld
Committee on Science and Technology
U.S. House of Representatives
Washington, D.C. 20515

Dear Dr. Holmfeld,

During the Science Policy hearing last July 9th we discussed briefly how to reconcile the facts that physics research appears to have fared extremely well in the federal budgets of the past few years, yet many of us in the universities feel that basic research - particularly in the areas of "small physics" - is starving for support.

Finding out how much federal money is actually spent for basic research in small physics presents a formidable problem due to the large number of agencies involved and the divergent views of what constitutes basic physics. In my own field - atomic, molecular and optical physics - we have figures that were obtained by the director of the NSF atomic and molecular program who personally surveyed the agencies every couple of years. This meant looking over individual grants and contracts and making judgements as to whether each research project was in physics, chemistry, engineering, and the like. These figures represent the majority of total support. Furthermore, they are internally consistent and provide what I believe is a credible description of funding in atomic and molecular physics. They form the basis of a comprehensive funding history that was prepared for the forthcoming N.A.S. physics survey report on Atomic, Molecular and Optical Physics. I am enclosing the final manuscript of Chapters 2 and 3 of the report (enclosure A) which has useful background information as well as the detailed funding figures on AMO physics. In addition, it discusses problems which are of concern to the Science Policy Study.

Funding from 1972 through 1983 is summarized in Chapter 3, Tables 3.1, 3.2 and Figure 3.1. (These can be found at the end of enclosure A.) The largest single source of support for AMO physics is the NSF program in atomic, molecular and plasma physics. The budget for the atomic and molecular component of this program from 1981-86 is as follows:

Year	Amount (thousands)	% Annual Increase
1981	$ 8,247	
1983	9,330	6.4
1984	10,000	7.2
1985	10,700	7.0
1986	11,100 (tentative)	4.0

The funding of the NSF atomic and molecular program has barely kept up with inflation over the past four years. Furthermore, and these increases are based on a budget which had fallen woefully behind the real needs of the field. The NSF program represents 35% of the total support for AMO physics. Approximately 15% comes from other divisions within NSF and the remainder from DoE Basic Energy Sciences, and DoD. Support from these agencies have not even kept up with the very modest increase of NSF. The DoD support for basic physics has actually dropped in current dollars! This can be seen in the ONR core physics figures, which were provided by the head of the physics division. (Attachment B)

As to where all the new money is going, I can only speculate. DoD is increasing its support for applied programs (some increases can be seen under the "SFP" budget in attachment B), apparently at the expense of basic research. NSF has increased its support for undergraduate education. Some of the new money is being siphoned off for big physics. For instance, for the years 1984-1986 the elementary particle physics program of NSF is budgeted at $35.1M, $40.5M and $44.8M respectively. Most of the increase is for upgrade of the Cornell accelerator CESR. CESR is widely regarded as a scientific success. Nevertheless, the recent increase in the NSF particle program roughly equals the total size of this Nation's core atomic and molecular physics program. Other money is being diverted to new projects, such as the NSF supercomputer initiative. This initiative can be expected to be very productive, and as far as I know it enjoys wide support in the scientific community. To me, it dramatizes how much easier it is to start new and visible programs rather than to maintain existing programs, particularly diverse programs in small physics. Another example is the rapidly growing NSF program in gravitational physics, including the prospect of a $30M gravitational antenna. The science is unquestionably first rate, but the lack of any comparable attempt to bring the NSF budgets for small physics up to a reasonable level is, I believe, a serious failure.

The viability of our universities is one of the questions on the agenda for the Task Force on Science Policy. The problem of support for small university groups is a crucial consideration to the future of university research in this country. In my opinion, both the NSF and the mission agencies should be much more responsive to the needs of small physics, and particularly the need to protect the support for this research in competition with new programs and major facilities.

Small physics is the backbone of physics in our universities. If the critical need for adequate support for this style of physics is not recognized, university research can be expected to deteriorate. As I described in the Physics Today article, signs of deterioration are already visible. I speak as a university research scientist, but all of the university administrators with whom I have talked share these concerns about the support of research and the future of the universities. The President of Harvard University, Derek Bok, has spoken to me of the central role of science in the university today and his concerns about maintaining the quality of science at Harvard and attracting outstanding young scientists to a university career. I hope that you will have the opportunity to hear such concerns, for they transcend the particular needs of various sciences and bear on the much broader problem of maintaining our scientific capability and meeting the needs of the future.

Yours sincerely,

Dan Kleppner

Daniel Kleppner
Lester Wolfe Professor
of Physics

MBT

Molecular Biophysics Technology, Inc.

3508 Market Street
Philadelphia, PA 19104
215-386-9800

19 August 1985

Dr. Mark K. Dickson
House Task Force on Science Policy
Rayburn House Office Building, Room 2318
Washington, DC 20515

Dear Dr. Dickson,

As physicists concerned about education, we were interested observers at the roundtable discussion that you moderated on July 15, on undergraduate and pre-college science and engineering education. We are writing to add some of our thoughts on the issues raised at that discussion. These observations grow out of our work on educational matters for the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics, but we write as individuals, not as spokesmen for these organizations.

Although some of the comments at the roundtable discussion were rather diffuse, it was an interesting session, with a significant consistency of viewpoint. In particular, we noted the following recurrent themes:

> The two faces of science education--training of scientists and general education for nonscientists--cannot be meaningfully separated.
>
> There is, similarly, a unity in the different stages of education. The production of scientific and engineering manpower rests as critically on pre-college education (including that in elementary school) as it does on advanced education.
>
> Continuity and stability of Federal programs are essential for effective support of education.

These are important points, which deserve to be kept in mind as specific plans and recommendations are formulated.

We were taken by the suggestion of Joe Meyer that a President's Council on Science and Technology be formed (analogous to the President's Council on Physical Fitness). Although not a matter for Congressional initiative, this is an appealing idea that merits consideration.

AMERICAN ASSOCIATION
OF PHYSICS TEACHERS
EXECUTIVE OFFICE

In our field of physics, an educational crisis exists. The fact that supply and demand for physics Ph.D.s are currently in balance (at around 900 per year) gives a false sense that all is well. Although the most serious elements of the crisis are at the pre-college level, even the Ph.D. numbers give cause for concern. At present, nearly half of the physics Ph.D.s awarded in the United States go to foreign students. This fraction may exceed 50 percent in the 1990s. In 1970, fewer than 20 percent of U.S. physics Ph.D.s went to foreign students. Over the course of the last 15 years, the number of American students earning Ph.D.s in physics has declined from about 1,300 annually to about 500 annually.

Consider, in addition, the following facts related to the crisis in physics education.

> The number of bachelor's degrees awarded annually in physics in the U.S. has declined from about 5,700 in 1970 to about 4,400 today (from 0.7 percent of all bachelor's degrees in 1970 to less than 0.5 percent today). This is an insufficient pool from which to generate an adequate number of advanced degrees in the years ahead.
>
> Fewer than 20 percent of high-school graduates have studied physics. Fewer than half of the high schools in the United States offer physics, and many of those that do offer physics use unqualified teachers.
>
> In 1976, 11 percent of students earning bachelor's degrees in physics went into high-school teaching. Now only 3 percent choose high-school teaching. In some states, the number is literally zero. In the nation, the supply of new high-school teachers qualified to teach physics is far less than the demand. (The demand may be more than four times the supply.)
>
> Women make up only 10 percent of bachelor's-degree recipients in physics. Minorities provide an even smaller percentage.

It seems clear that the scientific and economic health of the nation requires that the Federal government join with state and local governments and the private sector in trying to solve the massive problems in science education that face us. We did not mention above--simply because we have no data--what may be the most serious arena of deficiency in science education: the elementary schools. All else depends on what happens in the early years.

In the paragraphs below, We suggest specific areas in which Federal programs may have the greatest beneficial impact.

PRE-COLLEGE EDUCATION

1. Data. The data needed for long-term program decisions are largely lacking. Statistical data, gathered on a regular, ongoing basis, are needed for numbers and qualifications of science teachers, science enrollments, hours devoted to science in elementary schools, hours and kind of laboratory experience at all levels, and other important measures.

2. In-service training. In the short term, no strategy is more important than helping existing teachers become more effective. In the past, summer workshops have been considered especially valuable.

3. Equipment and supplies. In most schools, budgets for scientific equipment and supplies are absurdly low. Modest help from Federal programs could make a big difference. Most educators agree that, at all levels, students need to do science, not just read about it.

4. Loans and incentives. It is essential that more young people be attracted to the science-teaching profession. In the long term, much better salaries will be required. Until that is achieved, certain incentives could usefully be applied--for instance, educational loans that are forgiven if the graduate chooses a career in pre-college teaching.

5. College-school links. Many of the nations schools are close to a college or university. Programs that encourage college-school links can be of great value, and can become effective on a relatively short time scale. Evidence gathered by the College High School Interaction Committee (sponsored by the American Physical Society and the American Association of Physics Teachers), although limited, suggests that such programs are highly regarded by participants on both sides.

Two other important problems are worth mentioning, even though they lie outside the scope of direct Federal action: teacher certification and teacher salaries. State and local governments should be encouraged to allow people who are well qualified in a scientific discipline and are interested in teaching to be hired as teachers without first meeting all of the usual certification requirements. A few states are doing this now.

Inadequate teacher salaries are at the root of the problems in pre-college science education in America. As a nation, we must address this problem, which means we must ask ourselves whether we really value education. The long-term economic health of this country requires that we respect education, and that we manifest that respect tangibly. The cost is enormous. The Federal government cannot, and should not, seek to address the problem alone. But Federal officials, including Congressional leaders, can seek to mobilize American opinion on behalf of quality in education. Unless we as a people recognize the importance of education (including science education) and are willing to pay adequately for it, there is no hope that we will achieve excellence in education, and little hope that we will retain technological leadership in the world.

COLLEGE EDUCATION

The priorities outlined below come in part from a recent survey of physics department chairmen.

1. Equipment. Colleges and universities continue to fall behind in their inventory of modern equipment for both teaching and research. Previous Federal programs have been helpful. There is still a large unmet need.

2. Undergraduate research participation. Everywhere that undergraduates participate in meaningful research, the results are applauded. Student research participation provides needed financial support, encourages students to choose science as a profession, and, especially at four-year colleges, assists professors to remain active as researchers.

3. Access to computers. The need for student access to computers, from PCs to Crays, is outgrowing the resources of colleges and universities. Federal assistance may be required.

4. Research in four-year colleges. Percentage enrollment in science is higher in many liberal-arts colleges than in universities generally, and these colleges provide more than their "share" of graduate students in science. Supporting the research of faculty members in these colleges can help them to continue contributing to the nation's scientific manpower.

5. Curriculum development. We believe that Federal support of curriculum development in science is presently needed on only a limited and selective basis. The meaningful inclusion of the computer in education, for instance, needs attention. But, by and large, the people and the means to use existing materials are more important than the generation of new materials.

6. Equal opportunity. Genuine equity in science education is a goal that we are approaching all too slowly. This is particularly true in physics. Adequate representation of women and minorities in science would go a long way toward meeting future manpower needs. Continued Federal efforts to encourage equity are essential.

We hope that these comments are of some help to the Task Force.

Sincerely yours,

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